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PRESSURE DROP IN TANK AND FLOAT VENT TUBES ON DIVING AIRPLANES

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SUMMARY

Laboratory equipment was set up that simulated the tank and float venting conditions that exist on diving airplanes undergoing rapid changes in altitude. Data from the laboratory tests are presented as curves that give the difference in pressure between the outside and the inside of tanks and floats on airplanes having a rate of change of altitude of 300, 400, and 500 miles per hour when descending from altitudes of 10,000 to 40,000 feet. The tanks and floats had volumes of 10, 20, 40, and 60 cubic feet and were equipped with venting tubes having inside diameters of 13/32, 21/32, and 37/32 inch and lengths of 2 and 12 feet. The laboratory results were checked against results from a flight test. A procedure was developed for calculating the pressure drop that exists in the venting tubes on diving airplanes.

INTRODUCTION

The pressure on the outside of airplanes increases considerably when they make long dives from high altitudes. Large pressure differences build up between the outside and the inside of the tanks and floats unless the venting tubes to the fuel tanks and to the floats on seaplanes are of sufficient size. Because of tank and float failures in service, the Bureau of Aeronautics, Navy Department, requested the NACA to investigate these pressure differences and to obtain data for use in the choice of vent-tube sizes.

Calculating the size of vent tube needed is a tedious process because of the changing air density and the changing diving velocity. Obtaining the necessary design data from test flights would be both dangerous and expensive. Except for the effect of temperature, a laboratory set-up can readily be made of tanks and vents that will simulate the tank and float venting conditions existing on airplanes. Calculations showed the effect of temperature variation on pressure drop through a vent tube to be so small that the results of tests at laboratory temperatures can be considered to represent closely those that would be obtained at the air-temperature conditions of a diving airplane.

The tests in the laboratory simulated terminal-velocity dives, which present the most severe conditions from considerations of pressures on tanks and floats and, if vents are designed for this condition, they will be sufficient for any other flight condition.

The tests were based on a static pressure at the entrance of the vent tube which is the same as that of the atmosphere. For an airplane, care must be taken to prevent a reduction in pressure in the end of the vent tube caused by air that flows past it. In most cases, it will be necessary to locate the entrance of a vent in a dead-air space or to point it slightly forward if it is in the air stream. Reference 1 gives the static pressure in tubes extending into air streams.

The rates at which the atmospheric pressure changes during terminal-velocity dives were obtained from references 2 and 3.

A flight test for one venting condition served as a check on the applicability of the laboratory results.

APPARATUS AND METHODS

The laboratory apparatus consisted essentially of two chambers separated by a diaphragm as shown in figure 1. The pressure in the upper chamber was varied in the manner in which it would change on a diving airplane. The volume of the lower chamber could be made to correspond to that of any fuel tank or seaplane float by varying the water level. A glass tube and a scale outside of this chamber showed the volume of air in the lower chamber. Various vent tubes were mounted in the diaphragm separating the two chambers.

The pressure in the upper chamber was regulated by a hand-operated valve according to the reading of the mercury manometer in front of the drum on which charts were mounted. These charts were so drawn that, when the mercury level was kept even with the line on the chart as the drum was turned at constant speed, the pressure in the top chamber varied as it would on the outside of an airplane diving under the conditions assumed in computing the chart.

The pressure differences between the upper chamber and the atmosphere and between the upper and the lower chambers were recorded by the NACA air-speed recorder (reference 4) used as a recording manometer. The record of the pressure difference between the upper chamber and the atmosphere was obtained as a check to insure that the pressure varied according to the assumed diving conditions. The record of the pressure difference between the upper and the lower chambers gave the drop in pressure caused by the vent.

A sample of the records obtained is shown in figure 2. The difference in pressure between the upper and the lower chambers is ΔP, and the difference in pressure between the atmosphere and the upper chamber is labeled "upper-chamber pressure." Two lines are labeled "upper-chamber pressure" because two mirrors were needed to record the desired range of pressure, the light beam from the second mirror coming onto the film slightly before the beam from the first mirror went off. The timing marks on the film occurred at 3-second intervals.

An electric switch was connected so as to start the recording manometer and the mercury-manometer drum simultaneously.

The two chambers of the laboratory apparatus were evacuated by a 2-horsepower electrically driven vacuum pump capable of evacuating the 60-cubic-foot tank down to the pressure existing at an altitude of 40,000 feet.

The following test conditions were used:

Inside diameter of tube (in.)	Length of tube (ft.)	Float volume (cu. ft.)	Terminal velocity of airplane (m.p.h.)	Altitude of start of dive (ft.)
13/32	2	10, 20, 40, 60	300, 400, 500	10,000 - 40,000
13/32	12	10, 20, 40, 60	300, 400, 500	10,000 - 40,000
21/32	2	10, 20, 40, 60	300, 400, 500	10,000 - 40,000
21/32	11	10, 20, 40, 60	300, 400, 500	10,000 - 40,000
37/32	2	10, 20, 40, 60	300, 400, 500	10,000 - 40,000
37/32	11-1/2	10, 20, 40, 60	300, 400, 500	10,000 - 40,000
3/16	12	4.55	Constant speed of 300 m.p.h.	20,000

The values given in the table for "terminal velocity of airplane" are the velocities the airplanes would reach if they were diving in air at sea-level conditions. Reference 2 gives the actual velocities reached by these airplanes in terminal-velocity dives.

All the vent tubes were made of standard smooth annealed copper tubing with no sharp bends and had clean square entrance and exit edges. The long tubes had to be coiled several times to fit into the testing chambers. The tubes with diameters of 13/32 and 21/32 inch were bent on a 6-inch radius and the 37/32-inch tube was bent on a 9-inch radius. Friction measurements with the 13/32-inch tube showed that the bends did not appreciably increase the friction. This result indicated that the flow in the tubes was turbulent (reference 5). Flush with the entrance end of each tube was mounted an 8-inch square plate to eliminate the effect of the air currents that undoubtedly existed in the upper chamber during tests. During some tests with the 3/16-inch-diameter tube, this end plate was removed and its effect on the pressure drop through the tube was found to be negligible, which showed that the results of this report also apply to venting conditions in which the tube entrance is not flush with a flat surface.

The procedure for running a test was to install a vent tube, set the lower-chamber volume, put the proper chart on the mercury-manometer drum, and evacuate the chambers to the desired pressure. Then the manometer switch was closed and the valve to the atmosphere regulated so that the mercury level stayed even with the line on the chart as the drum revolved. When the mercury column reached the bottom of the chart, the manometer switch was opened.

Thus, in the laboratory tests a pressure was maintained at the entrance to the vent tube that corresponded to the pressure on the free end of a tube venting a tank or float on a diving airplane. The other end of the experimental vent tube opened into a volume equal to that of the vented tank or float on the diving airplane.

The flight test was made with a 4.55-cubic-foot tank (fig. 3) placed in the baggage compartment of a P-29 airplane. The tank was of 1/16-inch aluminum, was 30 inches long, and had two inside baffles to prevent collapse during the dive. The long tube shown attached to the side of the tank is the vent. The short tube on the end is the connection for the recording manometer.

Although the fuselage of the airplane was of tight monocoque construction, venting louvers on the bottom allowed the pressure inside the fuselage to vary with that on the outside.

Figure 4 shows the location of the tank and the instruments in the airplane. The altimeter gave a record of pressure change with time inside the fuselage and the recording manometer gave a record of the difference in pressure between the inside of the fuselage and the inside of the tank. The interval timer simultaneously placed 3-second timing marks on the manometer and altimeter records.

CALCULATIONS

Before the construction of laboratory apparatus for making tests, it was necessary to determine the amount of error introduced by running the tests at constant temperature instead of varying the temperature as it would vary on a diving airplane. Because actual measurements of the effect could not be made with the apparatus available, the pressure drop in the vent tubes was calculated.

The loss of static pressure when air flows through a tube under these conditions is caused by the entrance drop, the acceleration drop, the jet-contraction drop, and the friction of the air against the tube.

The loss of pressure caused by the entrance drop, the acceleration drop, and the jet-contraction drop is:

$$\Delta P_1 = 1.4 \frac{v^2 \rho}{2} \qquad \text{(reference 6, p. 52)} \qquad (1)$$

where

ΔP_1 is the pressure loss, lb./sq. ft.

v, velocity of air in tube, f.p.s.

ρ, air density, lb./cu. ft.

There are several methods of computing the loss of pressure caused by friction. Some preliminary friction investigations with a 1/2-inch by 12-foot vent tube were made and the equation of Blasius (reference 6, p. 42) was found to be most nearly correct for expressing this pressure drop. His equation is

$$\Delta P_2 = \lambda \rho \frac{l}{r} \frac{v^2}{2} \tag{2}$$

where

ΔP_2 is the pressure loss, lb./sq. ft.

$\lambda = \frac{0.1582}{\sqrt[4]{R}}$

R, Reynolds Number $(\rho v d/\mu)$

d=$2r$, diameter of tube, ft.

μ, absolute viscosity, lb./sec. ft.^{2}

l, length of tube, ft.

The velocity of the air in the tube used in the calculations was the mean velocity across the tube. Because of the change in density, the velocity at the exit of the tube was higher than that at the entrance. The correct method of computing the loss of pressure along the tube caused by friction would have been to sum up the pressure drop along the tube as the velocity varied, but this method would have been too complex. Sample calculations were made using the mean velocity and density at the entrance, at the midway point, and at the exit of the tube. The computations made with the mean velocity and density midway between the ends of the tube fitted the experimental values most closely.

Figure 5 shows a comparison between the calculated and the experimental results. The lower solid line is a calculated curve, whereas the points are taken from experimental curves. Another comparison between calculated and experimental results can be obtained from figures 7 and 16.

The upper curve in figure 5 was obtained from references 2 and 3 and is the atmospheric pressure on the diving airplane plotted against time of descent. The calculations were a step-by-step process taken at intervals of 2-1/2 seconds, starting from zero time when the pressures inside and outside the float were the same. Two and one-half seconds after zero time the pressure on the outside increased by an amount obtained from the atmospheric-pressure curve. This increased pressure caused air to flow through the vent and increase the pressure inside the float. The rate of flow through the vent depended on how much the inside pressure built up and the amount this pressure built up depended on the rate of flow. It was therefore necessary to estimate either the pressure or the rate of flow, compute the other, and then correct the estimate.

The velocity was estimated in the computation of the lower curve in figure 5. The velocity at the end of each 2-1/2 second interval was estimated, the average velocity during this interval was determined, and the weight of air that would flow into the float in 2-1/2 seconds with this average velocity was then computed. From the weight in the float, the pressure was computed. This velocity, estimated at the 2-1/2 second point, caused a velocity-head pressure drop in the vent tube that was given by equation (1) and a friction pressure drop that was given by equation (2). When these friction and velocity-head pressures were added, they were required to equal the pressure obtained by deducting from the pressure outside the float the computed pressure inside the float. If this sum did not equal this difference, successive estimates of velocity and pressure were made until the values checked. The foregoing procedure was continued until the curve of the pressure in the float during the entire dive was obtained.

A sample of the calculations made for figure 5 follows:

<u>Time: 2.5 seconds after start of dive</u>

$P_{o(tank)}$ = 8.84 in. Hg, starting point.

$P_{2.5(tank)}$ = 8.85 in. Hg, estimated.

$P_{o(atmos.)}$ = 8.84 in. Hg, starting point.

$P_{2.5(atmos.)}$ = 8.90 in. Hg, from top curve.

$v = 20.0$ f.p.s., estimated.

$$v_{av.} = \frac{20.0}{2} = 10.0 \text{ f.p.s. average during the 2-1/2 sec.}$$

$$\rho_0 = 0.0765 \times \frac{8.84}{29.92} = 0.0226 \text{ lb./cu. ft.}$$

$$\rho_{2.5} = 0.0765 \times \frac{8.85 + 8.90 - \left[\frac{1.4 \times 0.0226 \times (20.0)^2}{64.4 \times 144 \times 0.49}\right]}{2 \times 29.92}$$

$$= 0.0227 \text{ lb./cu. ft.}$$

$$\rho_{av.} = \frac{0.0227 + 0.0226}{2} = 0.02265 \text{ lb./cu. ft.}$$

Weight flowing into tank in 2.5 sec. =

$$\frac{13^2 \times \pi \times 2.5}{64^2 \times 144} \times 0.02265 \times 10.0 = 0.00051 \text{ lb.}$$

$$P_{2.5(tank)} = 8.84 + \frac{53.3 \times 519 \times 0.00051}{0.49 \times 144 \times 60} = 8.843 \text{ in. Hg.}$$

$$\Delta P_{(tube)} = P_{2.5(atmos.)} - P_{2.5(tank)} = 8.90 - 8.843 = 0.057 \text{ in. Hg.}$$

Checking:

$$\Delta P_1 = \frac{1.4\rho v^2}{2} = \frac{1.4 \times 0.0227 \times (20.0)^2}{64.4 \times 144 \times 0.49} = 0.0028 \text{ in. Hg.}$$

$$\Delta P_2 = \frac{0.1582}{\sqrt[4]{R}} \rho \frac{l}{r} \frac{v^2}{2}$$

$$= \frac{0.1582 \times 0.0227 \times 12 \times (20.0)^2 \times 64 \times 12}{\sqrt[4]{\frac{0.0227 \times 20.0 \times 13}{32 \times 12 \times 1.195 \times 10^{-5}}} \times 13 \times 64.4 \times 144 \times 0.49}$$

$$= 0.0374 \text{ in. Hg.}$$

$$\Delta P_{(tube)} = \Delta P_1 + \Delta P_2 = 0.0028 + 0.0374 = 0.0402 \text{ in. Hg.}$$

Another estimate of v is necessary since the two values of $\Delta P_{(tube)}$ of 0.0402 and 0.057 inch of mercury do not check. If v is taken as 24.0 feet per second, the two values check very closely.

The foregoing calculations are for a standard temperature of 59° F.

After the experimental values were checked against the calculated values, the pressure in the float was computed with the temperature of the air entering the vent tube varying as it would on a diving airplane. Included in figure 6 are the curves for the varying-temperature and the constant-temperature conditions computed for a very short tube of 1/2-inch inside diameter. The maximum difference between the two curves was about 0.3 inch of mercury, which is 2.3 percent of the pressure drop of 13 inches of mercury through the tube. The indications are, then, that an inappreciable error is introduced by running the tests at a constant temperature. In these calculations, a value of the viscosity of the air at a standard temperature of 59° F. was used and was not considered to change with temperature since only the fourth root of its variation would have entered the final result.

Figure 6 also shows the calculated pressures built up in this float with several other sizes of tube. With the 1-7/8-inch tube, there was almost complete equalization of pressure between the outside and the inside of the largest floats to be tested; therefore, there was no need of using this size tube in the tests. The 13/32-inch tube was little better than no tube. Inasmuch as float volumes one-sixth as large as this largest size were to be used, it was decided to test vents as small as 13/32 inch.

Figure 7 shows the effect of increasing the length of a 37/32-inch tube from 12 to 18 feet. The pressure drop obtained with the two lengths differed by only 0.6 inch of mercury. With tubes of 13/32-inch diameter both calculations and tests showed about 0.5 inch of mercury difference in pressure drop to exist between dives with 12- and 18-foot lengths. These conditions being extreme, the small differences made it seem inadvisable to run a complete series of tests with 18-foot tubes.

FLIGHT TESTS

The flight made for the purpose of checking the laboratory results was started at an altitude of 20,000 feet and the airplane was dived at a constant indicated speed of 300 miles per hour.

Before the dive the tank used in the airplane had flat sides. Although the tank was unusually heavy and had two internal braces in a length of 30 inches, figure 3 shows that the sides of the tank were bent in between the braces during the dive.

After the flight was finished, a run was made with the laboratory tank; a volume of 4.55 cubic feet in the lower chamber and a pressure-time curve that corresponded to the altimeter record obtained during the flight were used. Figure 8 shows the pressure curves obtained with the airplane and in the laboratory. The laboratory run showed a pressure drop through the vent of about 0.5 inch of mercury greater than that obtained with the airplane. Calculations based on a varying atmospheric temperature but a constant tank temperature indicated that the pressure obtained with the airplane would be slightly below that obtained in the laboratory. Since the reverse was true, the tank in the airplane may have increased in temperature as the dive progressed and gave an increase in the pressure in the tank owing to an increase in tank temperature. The curves obtained in the two types of test show that the laboratory data are sufficiently accurate to be used for the design of vent tubes. As the laboratory tests show a greater drop through the vent tube than the flight test, the discrepancy is on the safe side and gives a slight factor of safety to vents designed from the curves obtained in the laboratory.

TEST RESULTS

The test data are presented in the form of curves (figs. 9 to 18) suitable for use in determining the correct vent diameter and length for various flight conditions. For each terminal velocity and for each tank or float volume, there is a figure presenting the results for each vent diameter and the two lengths tested. The altitude from which the dive starts is represented by the altitude when $\Delta P = 0$. The curves then represent the pressure differential between the atmosphere and the float or tank as the airplane descends. All values of ΔP given hereinafter are the values that would be reached if the airplane descended from the initial altitude to sea level (altitude = 0).

Figure 9(a) shows the results obtained for a terminal velocity of 300 miles per hour, a tank or float volume of 10 cubic feet, and a vent-tube diameter of 13/32 inch. This terminal velocity and the float volume were the least severe venting conditions used in the laboratory tests. Even then, the pressure difference ΔP between the outside and the inside of the tank reached a value of 7.3 inches of mercury for the 12-foot tube with a descent starting at 40,000 feet. With the lowest starting altitude of 10,000 feet, the ΔP was 3.8 inches of mercury, almost twice the maximum value of 2 inches of mercury that would probably be allowed for float design. A 13/32-inch tube would therefore not be large enough for this size of tank or float if the vent had to be 12 feet long. With the 2-foot tube length, the ΔP was 2 inches of mercury with a start from a 40,000-foot altitude and 1.2 inches of mercury with a start from a 10,000-foot altitude, a satisfactory vent for this size of float.

Increasing the tank of float size to 20 cubic feet (fig. 9(b)) raised the ΔP to 13.8 inches of mercury with the 12-foot tube length and to 7.4 inches with the 2-foot tube length when the dive started at 40,000 feet. With a dive starting at 10,000 feet, the ΔP was 5.6 and 3.4 inches, respectively, for the two lengths, showing that all lengths of 13/32-inch tube would be unsatisfactory for floats with a volume of 20 cubic feet.

With the floats of 40 and 60 cubic feet volume (figs. 9(c) and (d)), the 13/32-inch tubes were still more unsatisfactory. As the float size increased, it was found that there was less difference between the values of ΔP obtained with the two different tube lengths because the values obtained with both lengths were approaching the maximum possible.

In the tests made for terminal velocities of 400 and 500 miles per hour, the values of ΔP were progressively larger than those obtained for the terminal velocity of 300 miles per hour.

Figures 12, 13, and 14 give the results obtained with the tanks having 21/32-inch vent tubes. This size of tube kept the value of ΔP below 2 inches of mercury for both tube lengths with 10-cubic-foot tanks or floats and would be satisfactory for terminal velocities of 300, 400, and 500 miles per hour, in dives from 40,000 feet. With 20-cubic-foot floats and a 2-foot tube, the ΔP was well below 2 inches of mercury for a terminal velocity of 300 miles per hour, slightly above 2 inches for 400 miles per hour, and nearly 3 inches for 500 miles per hour in 40,000-foot dives. Vent tubes 12 feet long on this 20-cubic-foot float gave a ΔP equal to 2.8, 4, and 5.4 inches of mercury for the three terminal velocities. The 40- and 60-cubic-foot floats gave values of ΔP ranging from 2 to 16 inches of mercury, the 2-inch drop corresponding to a 10,000-foot dive by an airplane with a terminal velocity of 300 miles per hour and with a 2-foot vent tube.

Figures 15, 16, and 17 show the results obtained with the 37/32-inch tubes. The values of ΔP were very small with this size of vent and became greater than 2 inches of mercury only with 12-foot tubes on 60-cubic-foot floats for terminal velocities of 400 and 500 miles per hour; the values of ΔP were 2.5 and 3.7 inches of mercury, respectively. With 10-cubic-foot tanks or floats, the ΔP was too small to be readily measured. With the 20-cubic-foot float, the values of ΔP were very small.

Figure 18 illustrates how the data can be combined and plotted in a form that may be more useful to designers. In this figure, the vent-tube diameter is plotted against the product of the float volume and the terminal velocity. This terminal velocity is the same as that used in the other figure legends. Figure 18 applies to dives starting at 40,000 feet and gives the vent diameter needed if the maximum value of ΔP to be reached in the dives is 1 or 2 inches of mercury. The data could be assembled into similar curves for any other altitude of dive start and for any other value of ΔP. The altitude of dive start is not critical, however, and any dive in which terminal velocity is reached would require, for these same values of ΔP, a vent-tube diameter only slightly different from the values given in figure 18.

CONCLUDING REMARKS

Large pressure differences build up between the outside and the inside of tanks and floats on diving airplanes unless the correct size of venting tube is used. The values of pressure difference are given in chart form for a range of diving conditions that should be sufficient for design purposes.

A step-by-step method of calculation can be used that gives accurate values of the pressure difference for any diving conditions.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 9, 1938.

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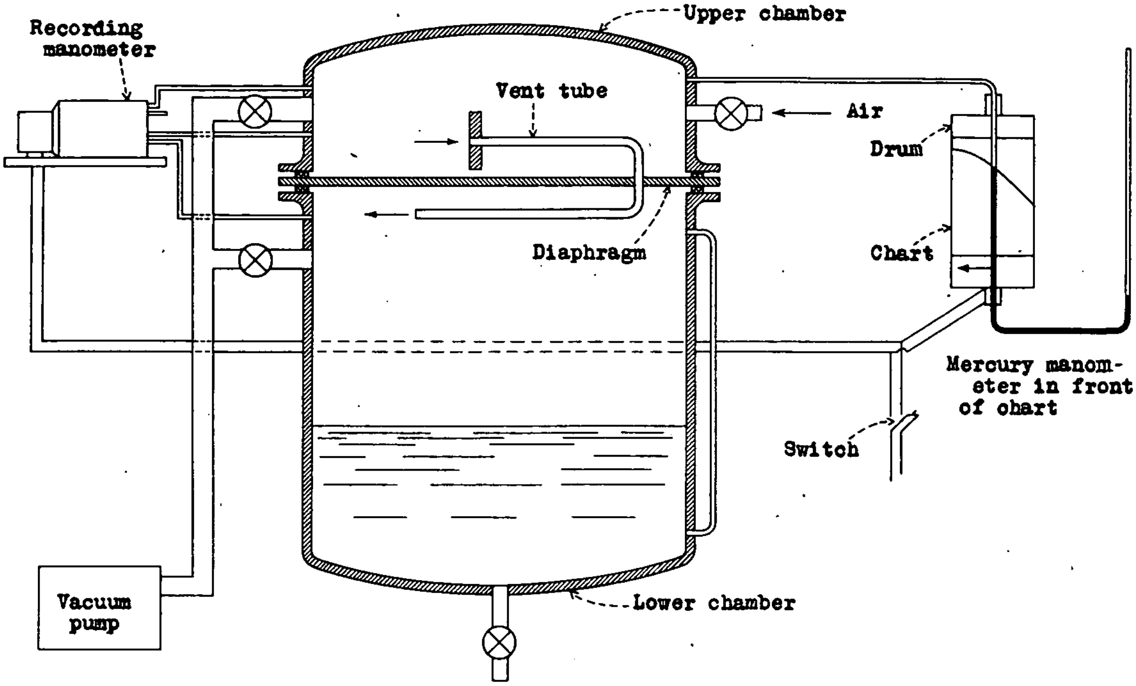


Figure 1.- Diagram of laboratory apparatus.
Volume of lower chamber, 60 cu.ft.

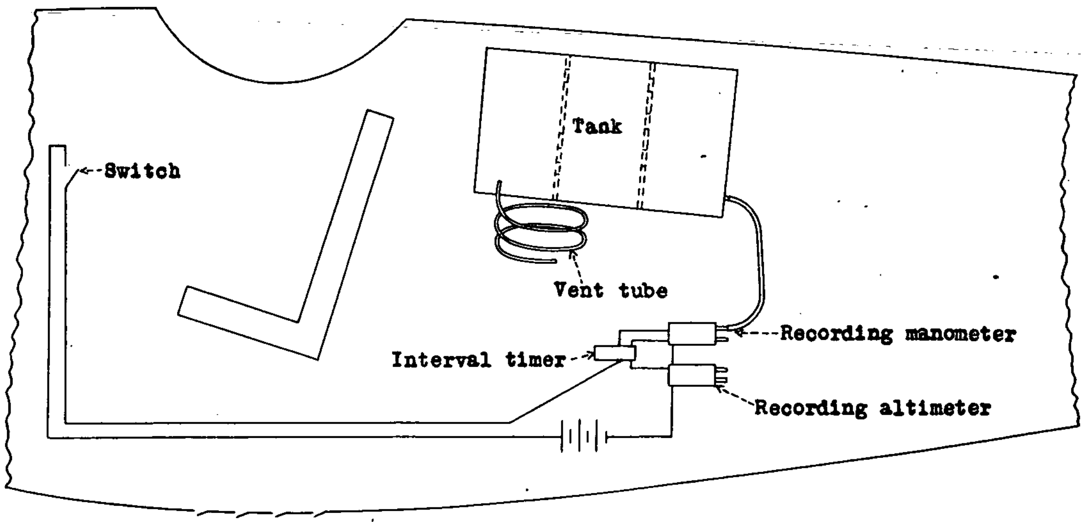


Figure 4.- Installation of apparatus for flight tests.

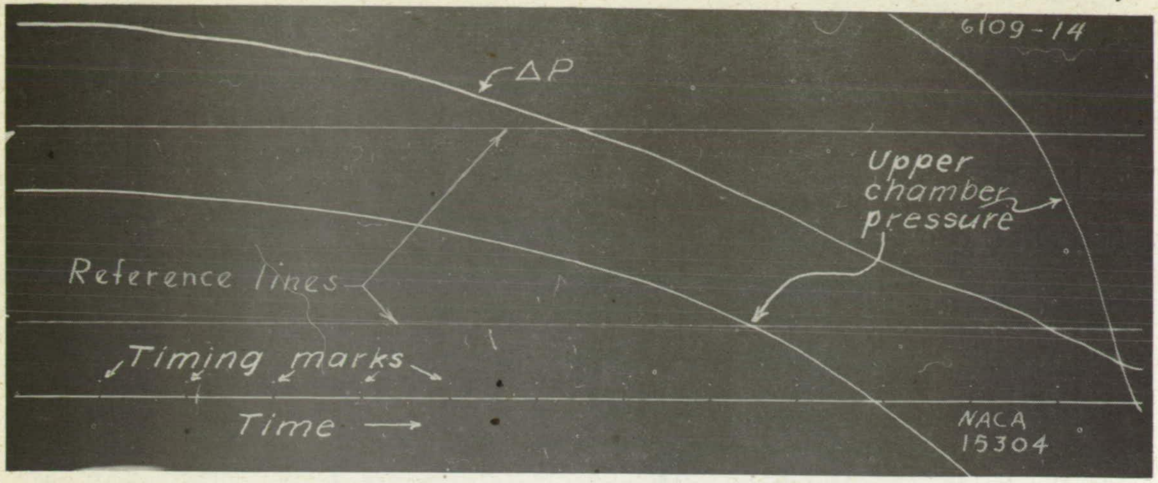


Figure 2. - Sample of records obtained from recording manometer.

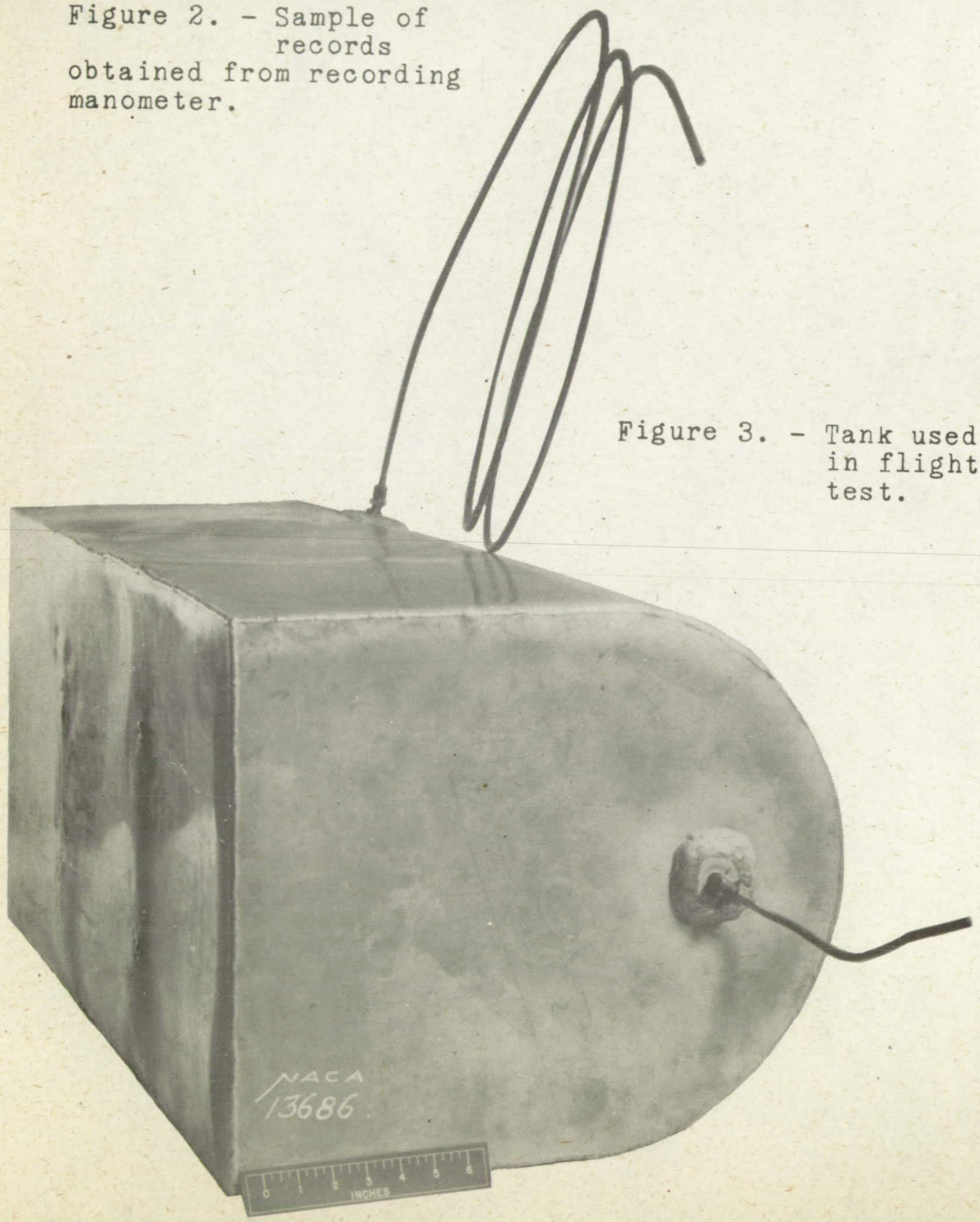


Figure 3. - Tank used in flight test.

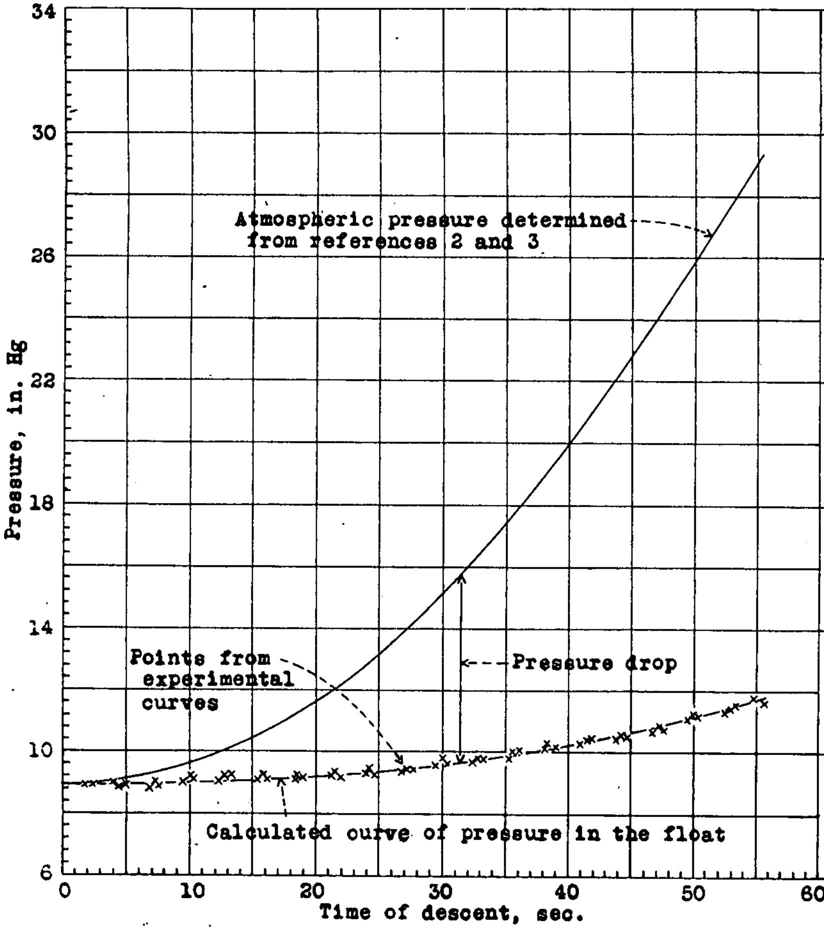


Figure 5.- Comparison of calculated pressure drop in a vent tube with experimental results. Float volume, 60 cu.ft.; altitude at start, 30,000 ft.; terminal velocity, 400 m.p.h.; inside diameter of vent tube, 13/32 in.; length of vent tube, 12 ft.

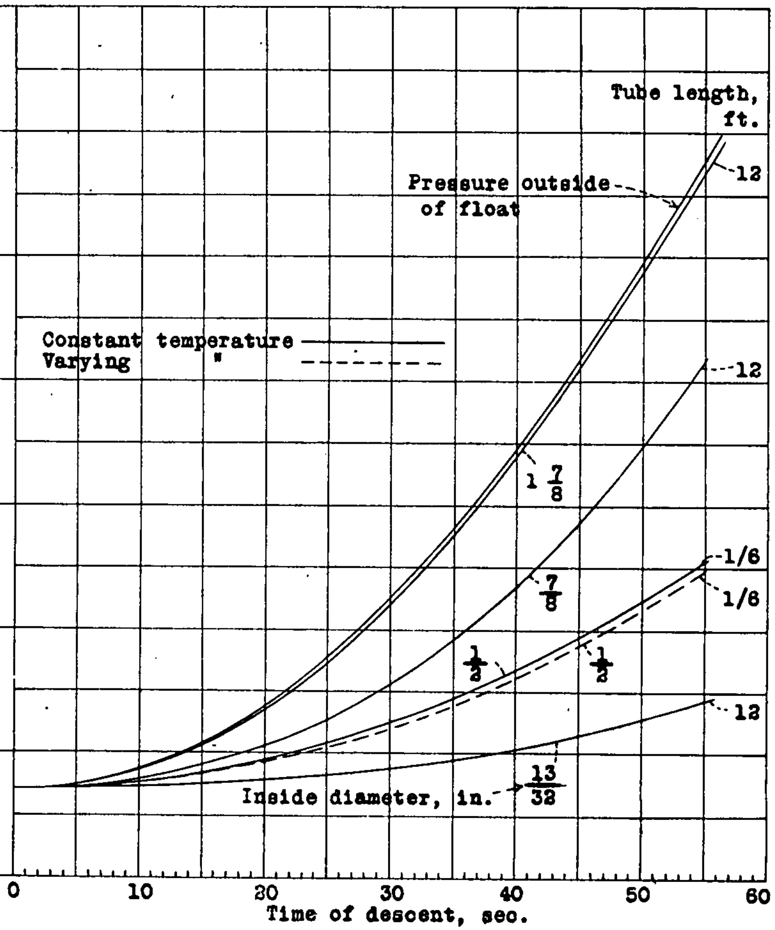


Figure 6.- Calculated pressures developed with different size vent tubes. Float volume 60 cu.ft.; altitude at start, 30,000 ft.; terminal velocity, 400 m.p.h.

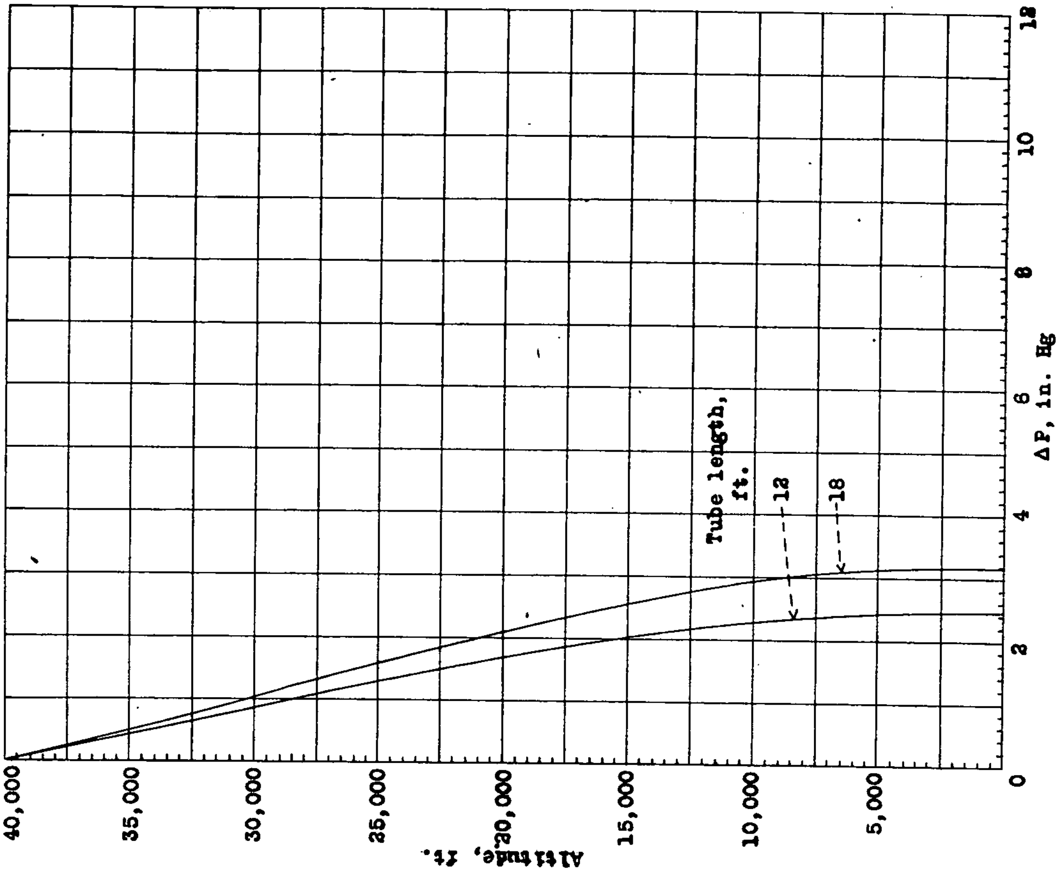


Figure 7.- Comparison of calculated results for 12 and 18 ft. lengths of vent tube with inside diameters of 37/32 in. Float volume, 60 cu.ft.; terminal velocity, 400 m.p.h.

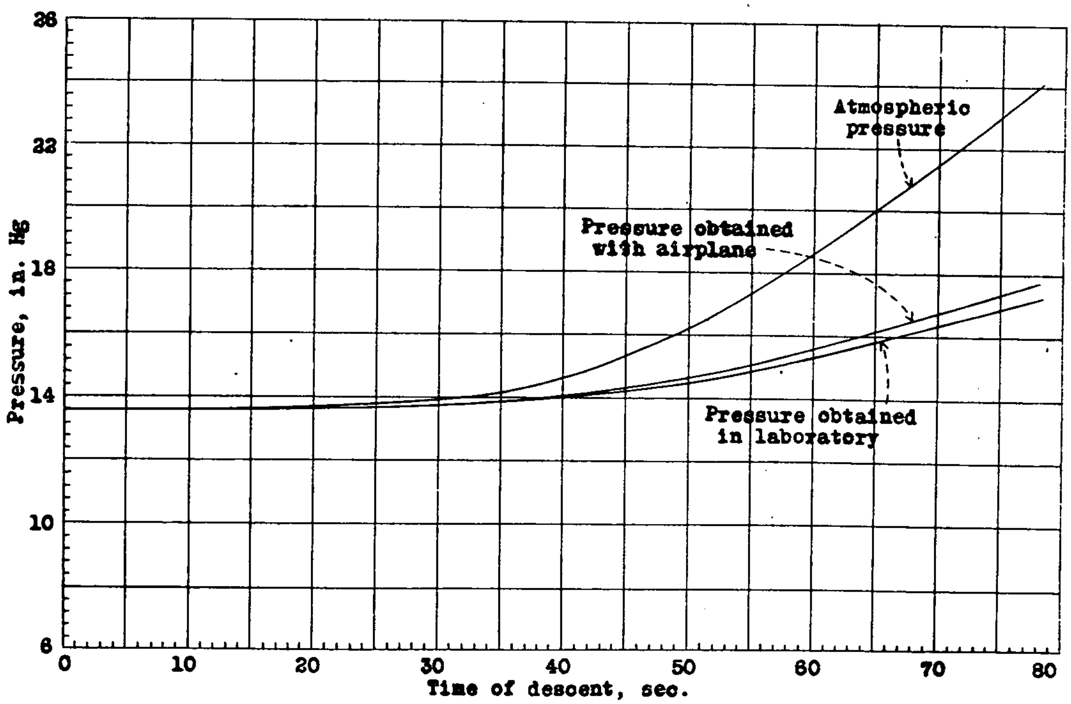
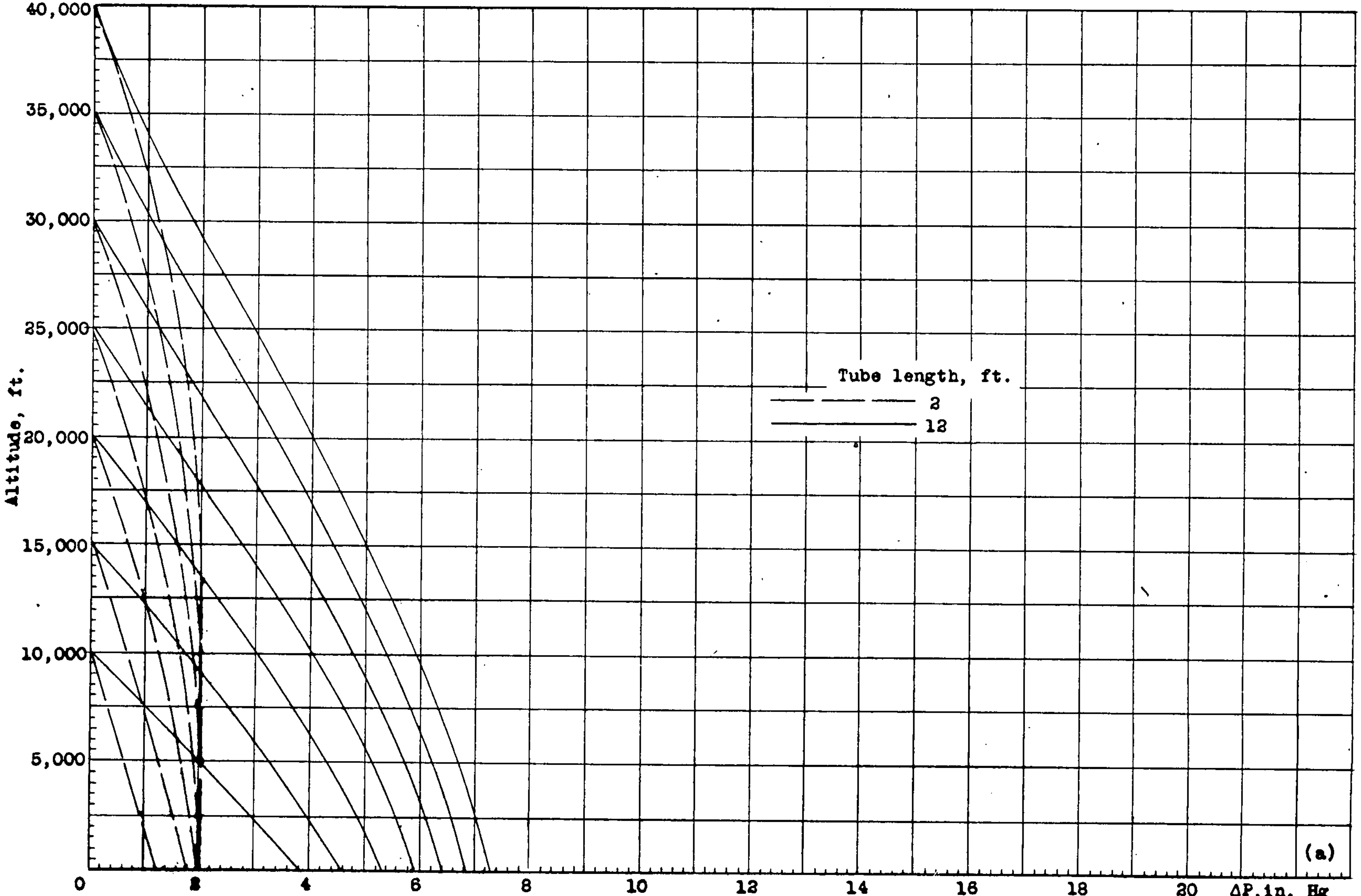


Figure 8.- Comparison of laboratory and flight results.



(a) 10 cu.ft., float volume

Figure 9.- Pressure difference developed during dives with a vent-tube inside diameter of 13/32 in. Terminal velocity, 300 m.p.h.

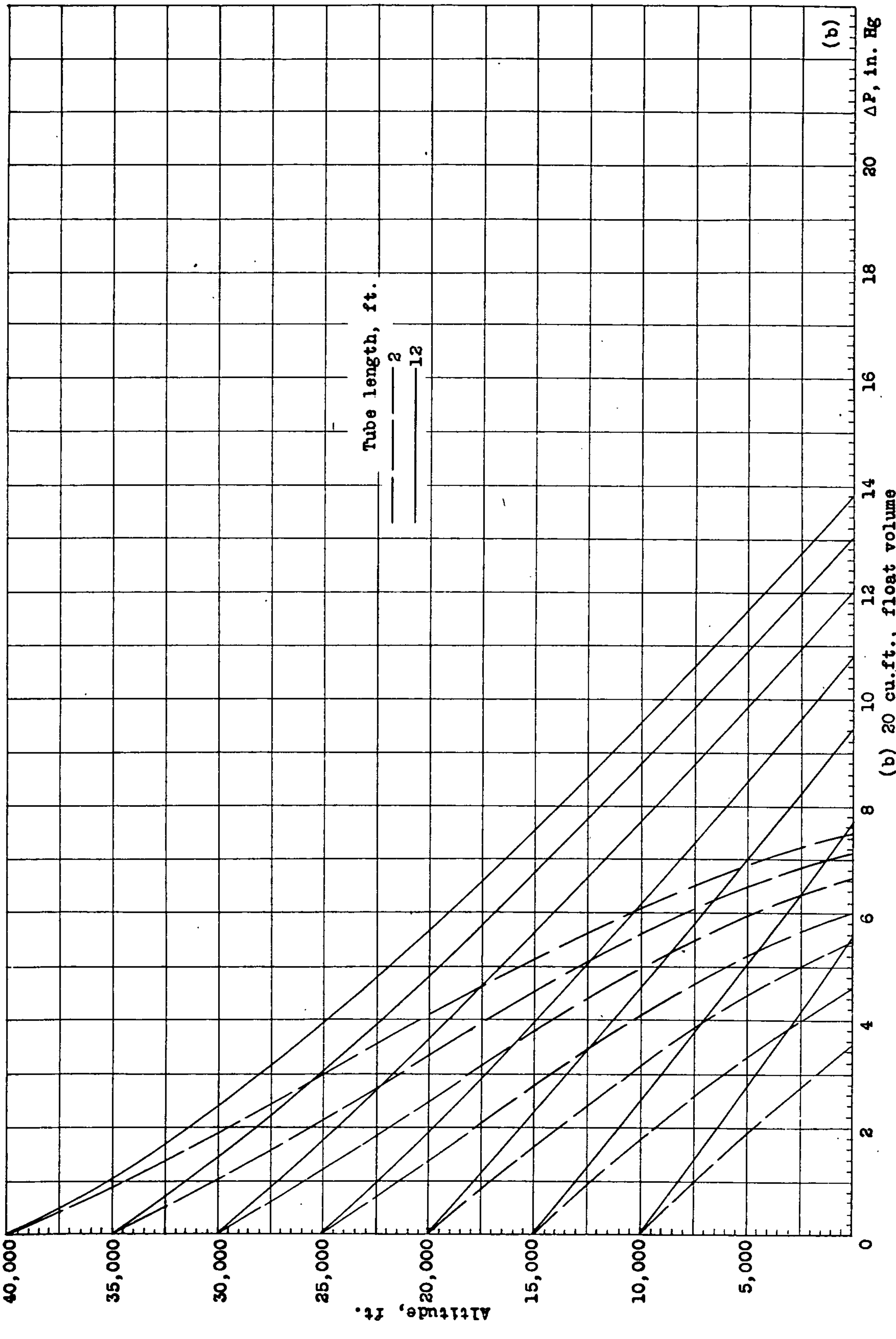
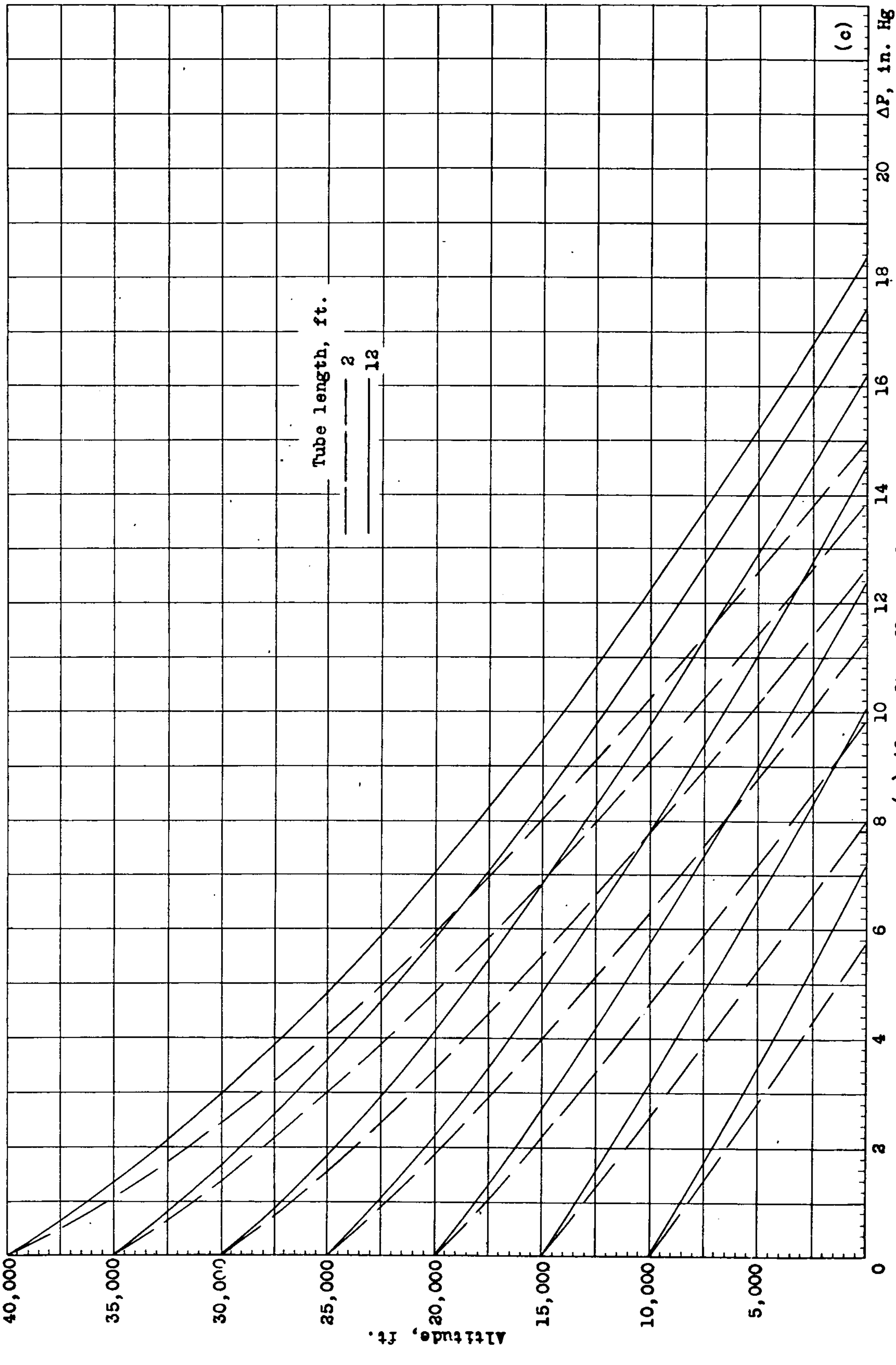

(b)
ΔP, in. Hg
Tube length, ft.
2
12
0
2
4
6
8
10
12
14
16
18
20
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
Altitude, ft.
(b) 20 cu.ft., float volume

Figure 9b.



(c) 40 cu.ft., float volume

Figure 9c.

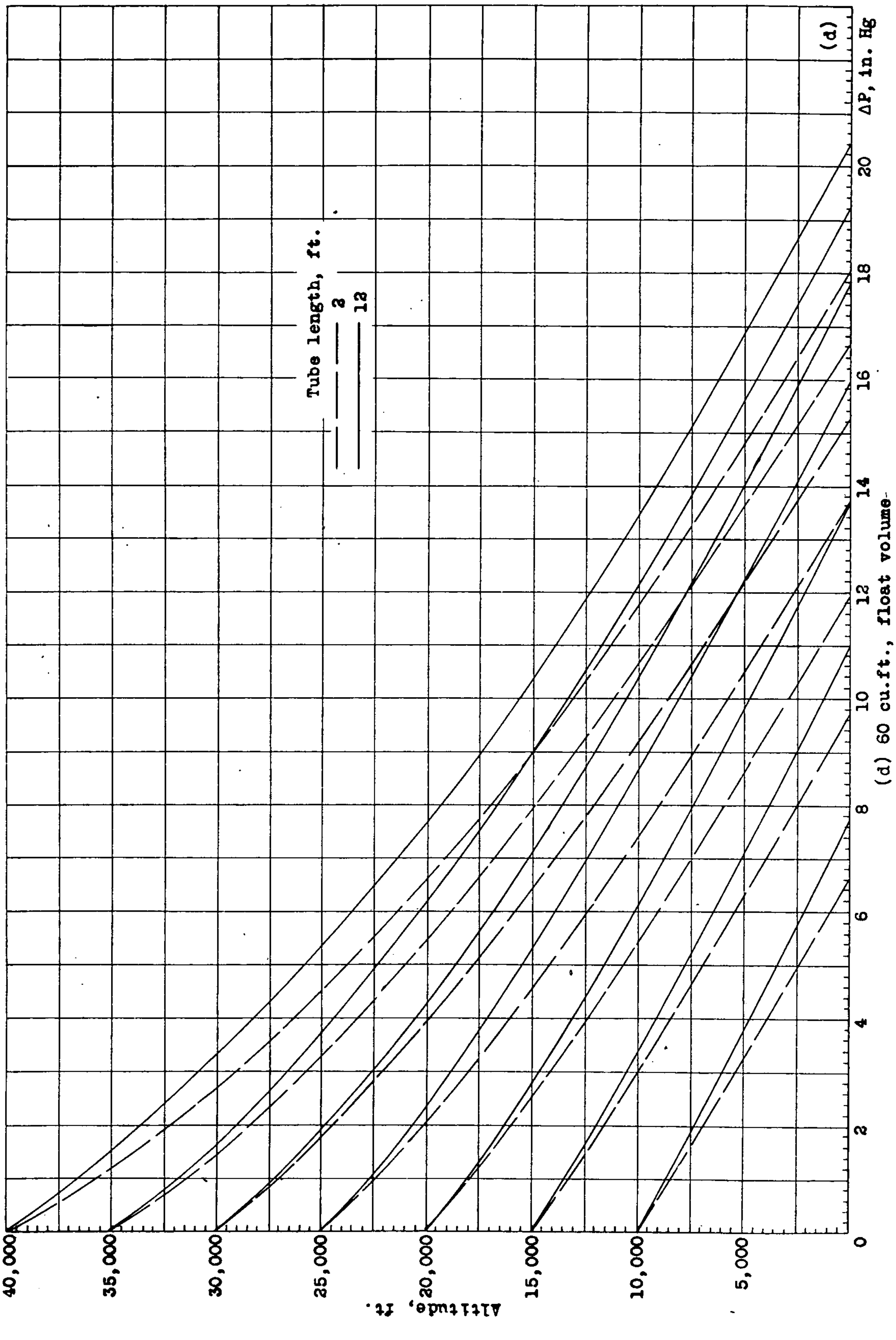
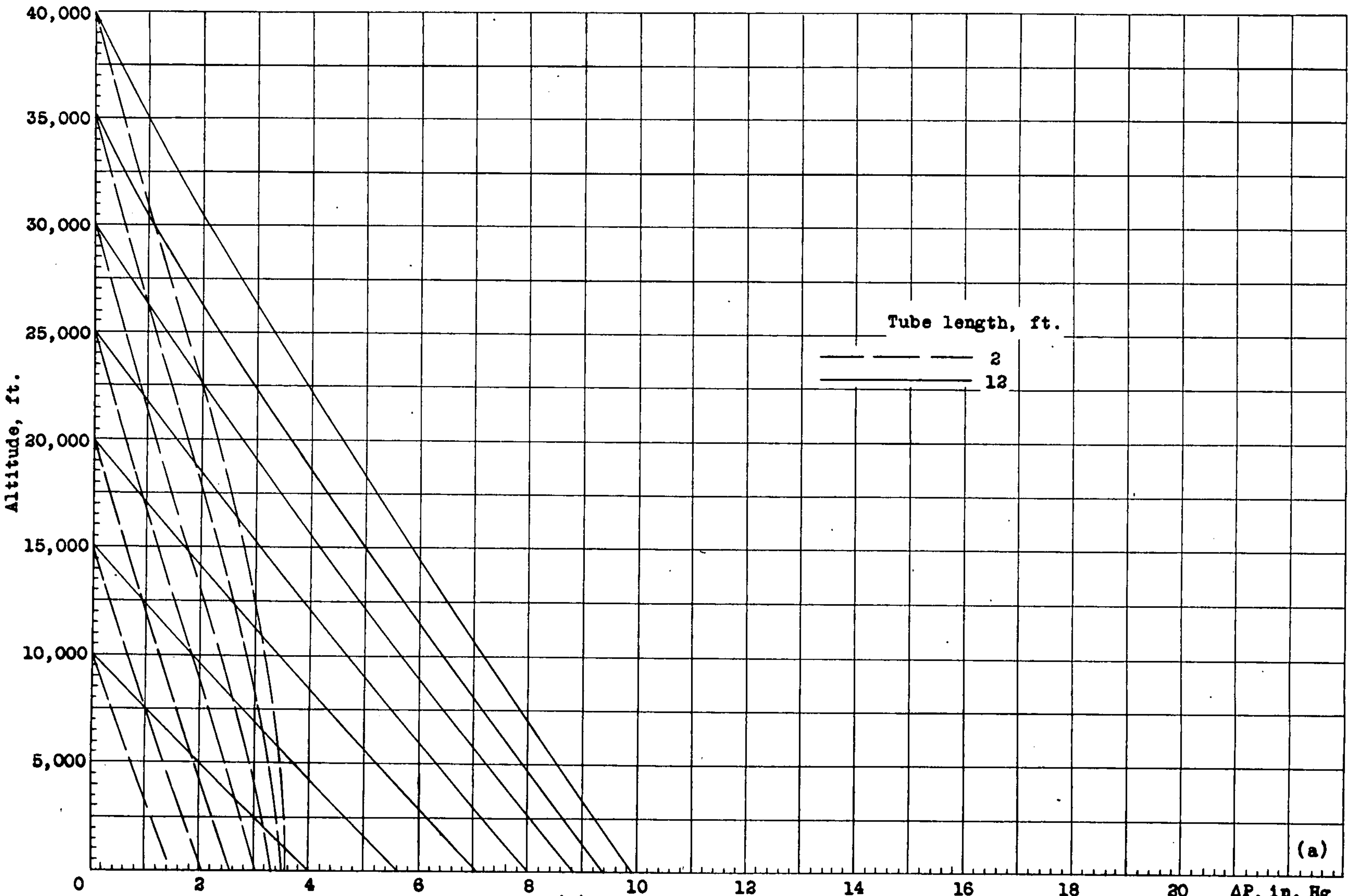

Tube length, ft.
2
12
(d)
ΔP, in. Hg
0
2
4
6
8
10
12
14
16
18
20
Altitude, ft.
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
(d) 60 cu.ft., float volume

Figure 9 d.



(a) 10 cu.ft., float volume

Figure 10.- Pressure difference developed during dives with a vent-tube inside diameter of 13/32 in. Terminal velocity, 400 m.p.h.

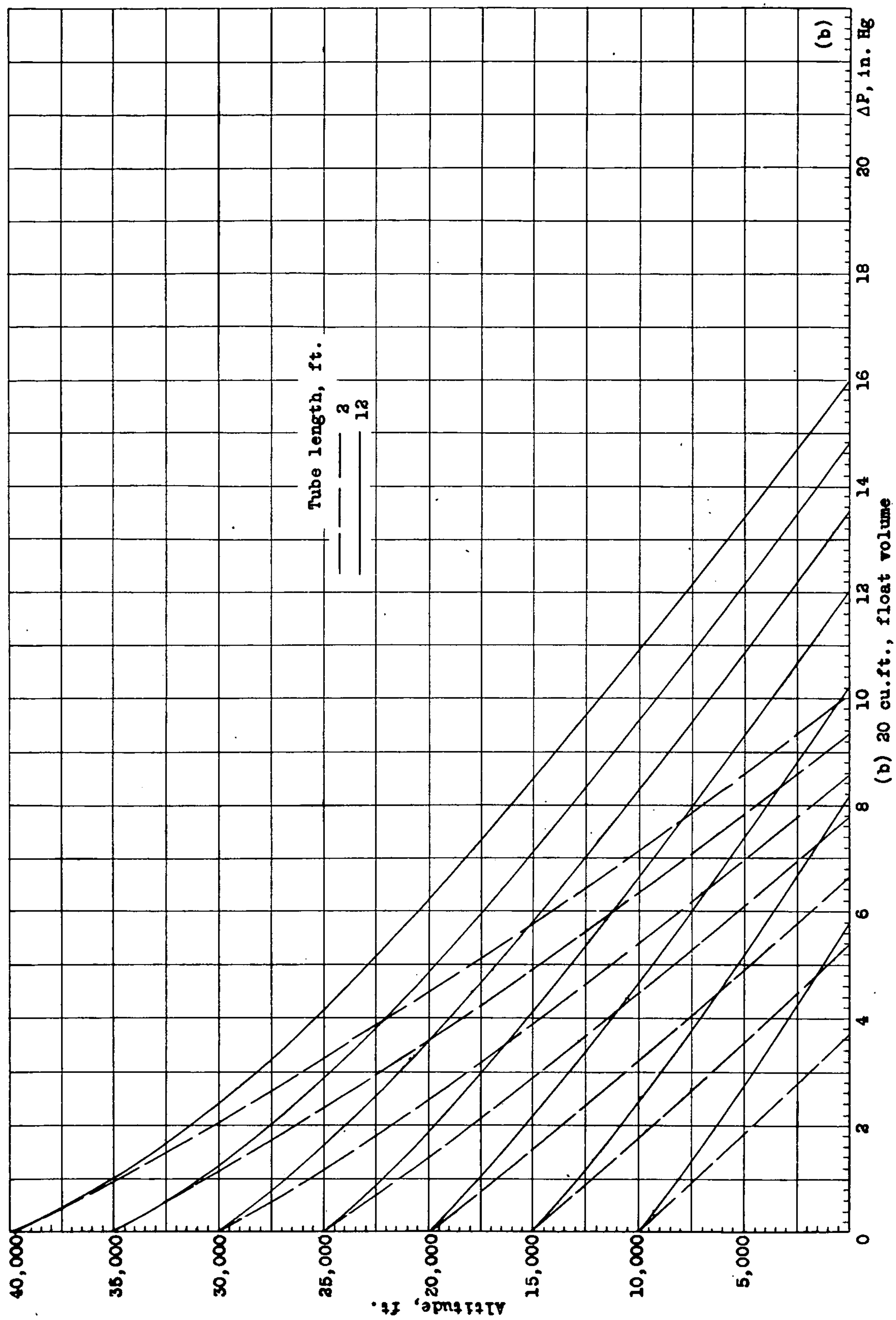
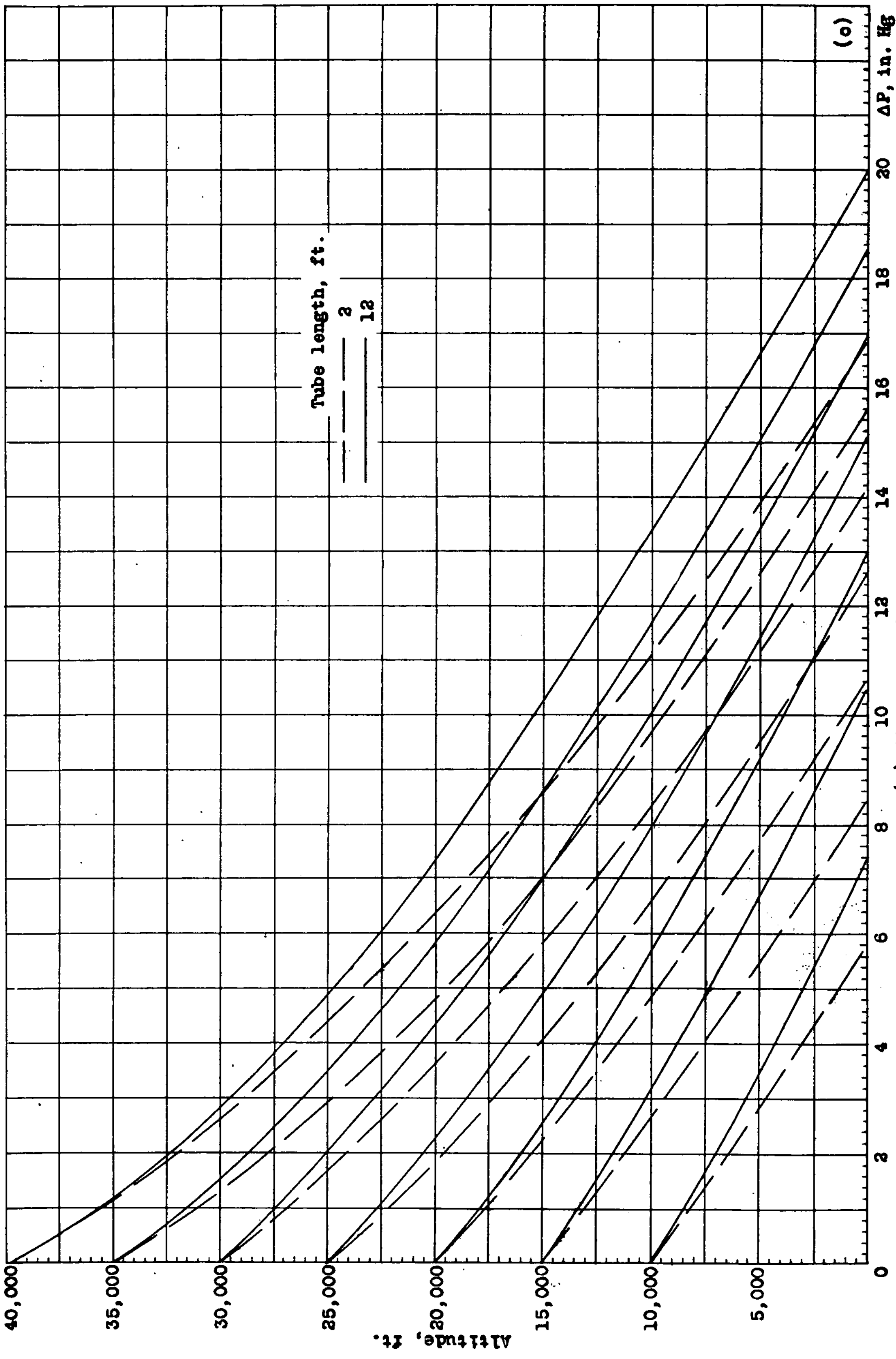

(b)
ΔP, in. Hg
0
2
4
6
8
10
12
14
16
18
20
Altitude, ft.
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
Tube length, ft.
3
12
(b) 20 cu.ft., float volume

Figure 10b.



(c) 40 cu.ft., float volume

Figure 10 c.

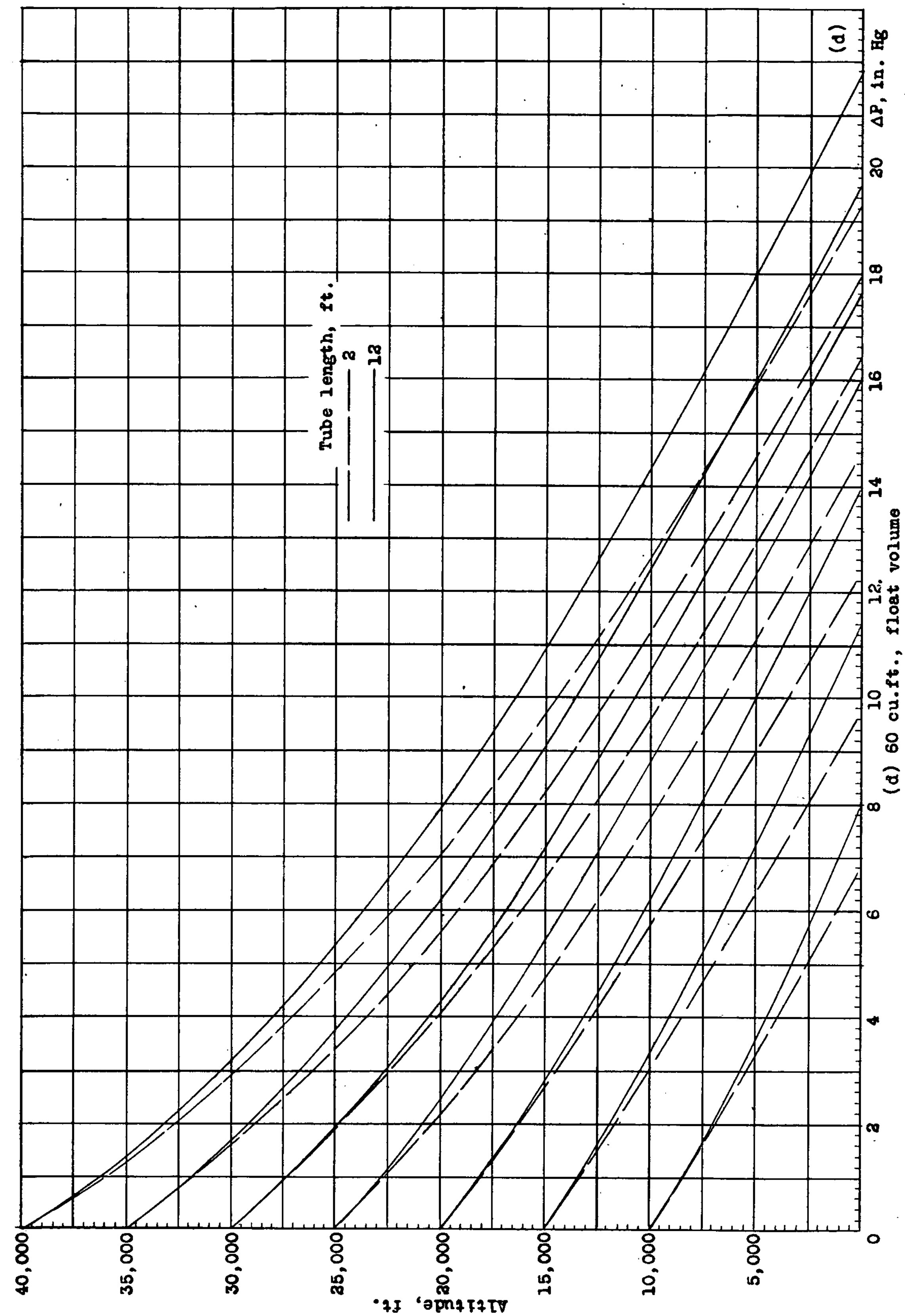
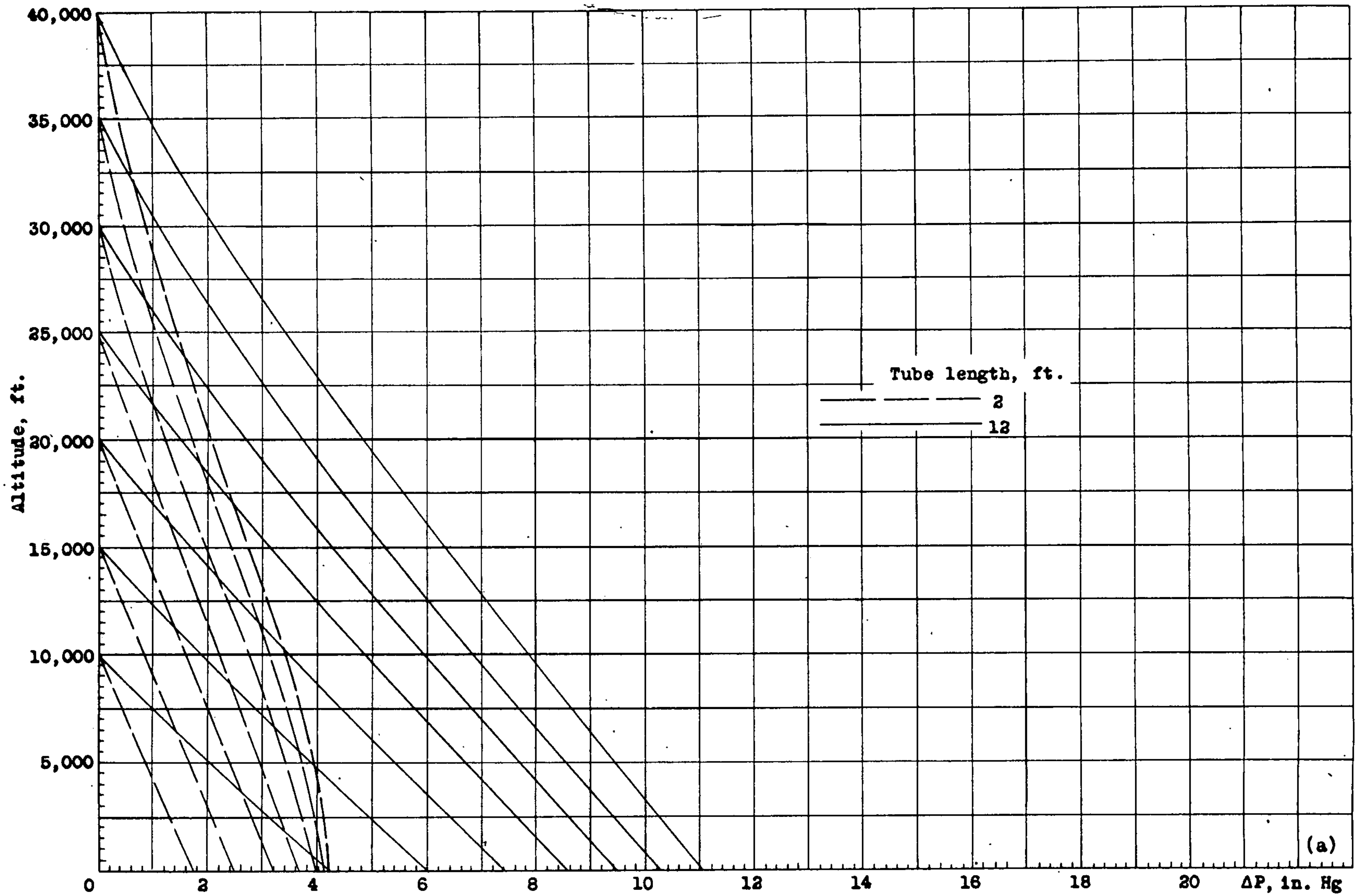
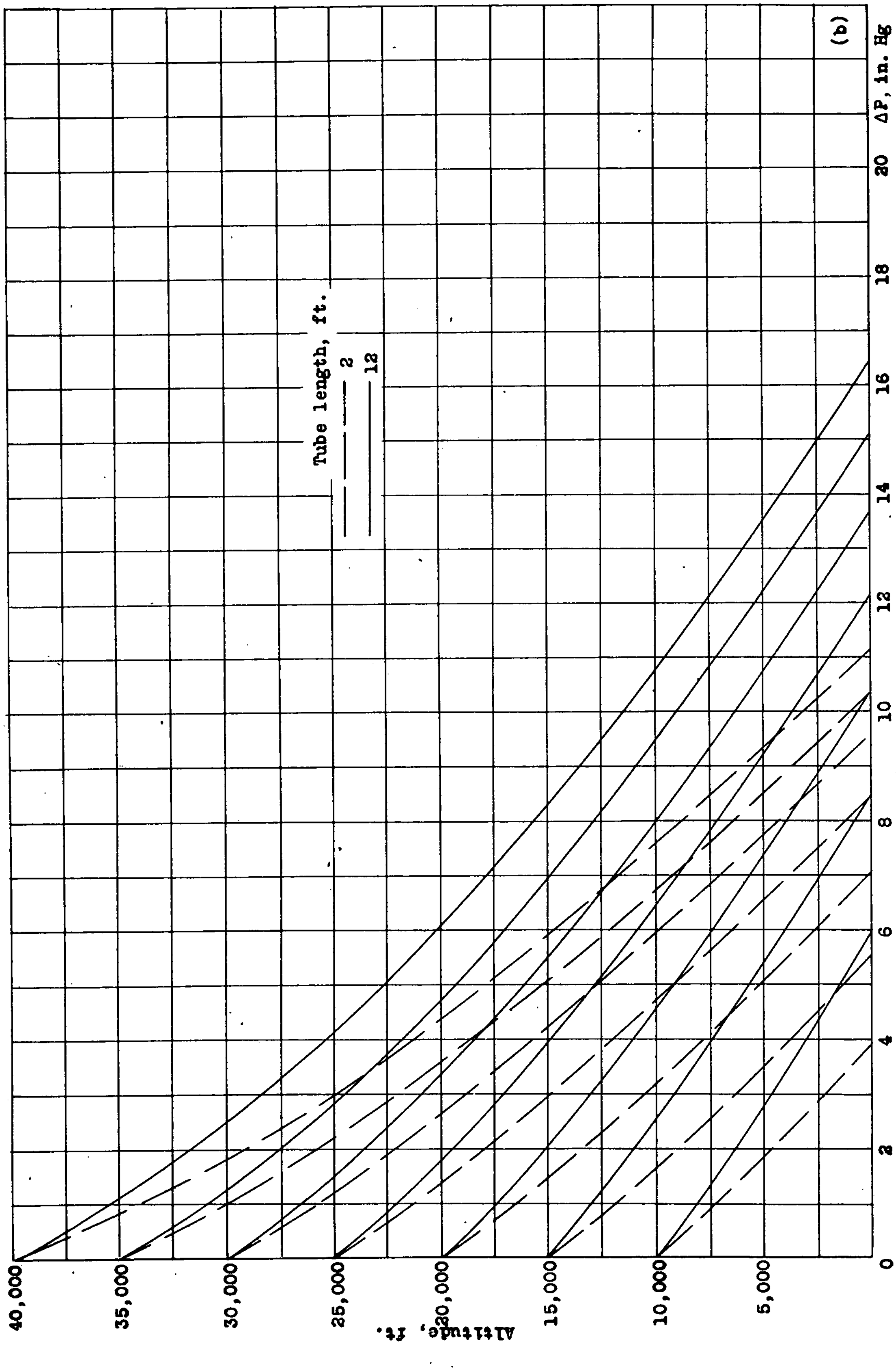

(d)
Tube length, ft.
2
13
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
Altitude, ft.
0
2
4
6
8
10
12
14
16
18
20
ΔP, in. Hg
(d) 60 cu.ft., float volume

Figure 10d.



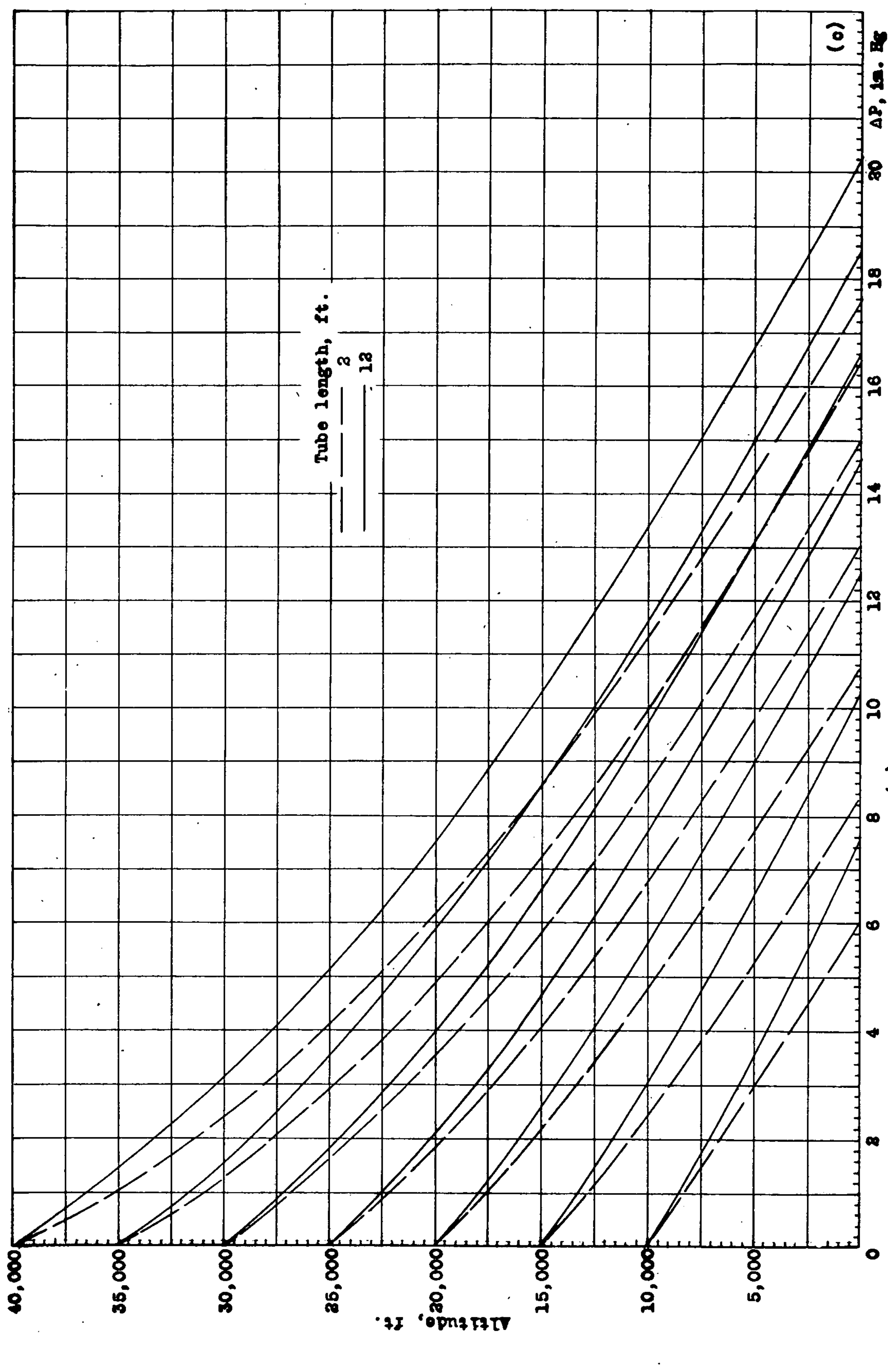
(a) 10 cu.ft., float volume

Figure 11.- Pressure difference developed during dives with a vent-tube inside diameter of 13/32 in. Terminal velocity, 500 m.p.h.



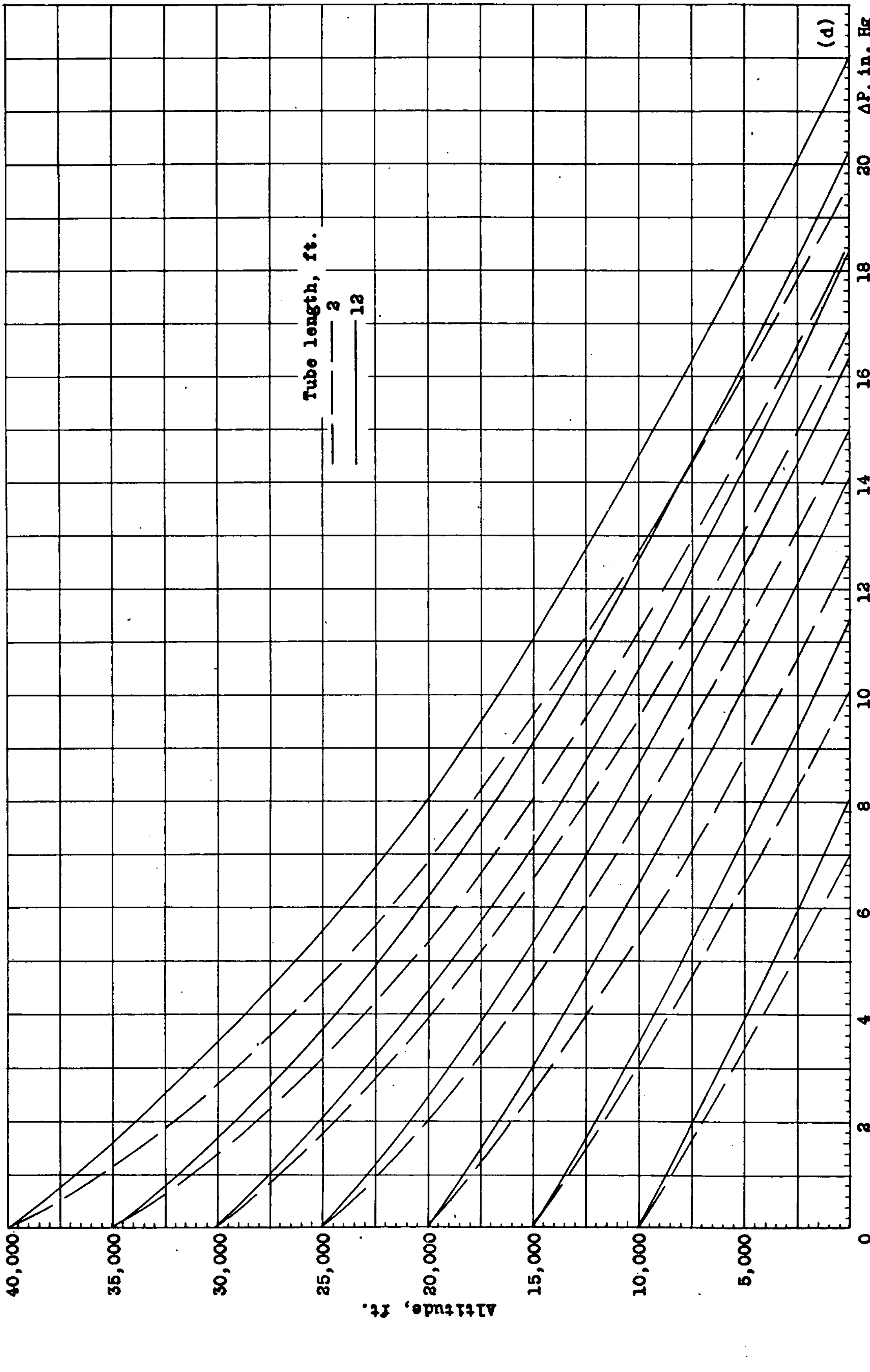
(b) 20 cu.ft., float volume

Figure 11b.



(c) 40 cu.ft., float volume

Figure 11 c.



(d) 60 cu.ft., float volume

Figure 11d.

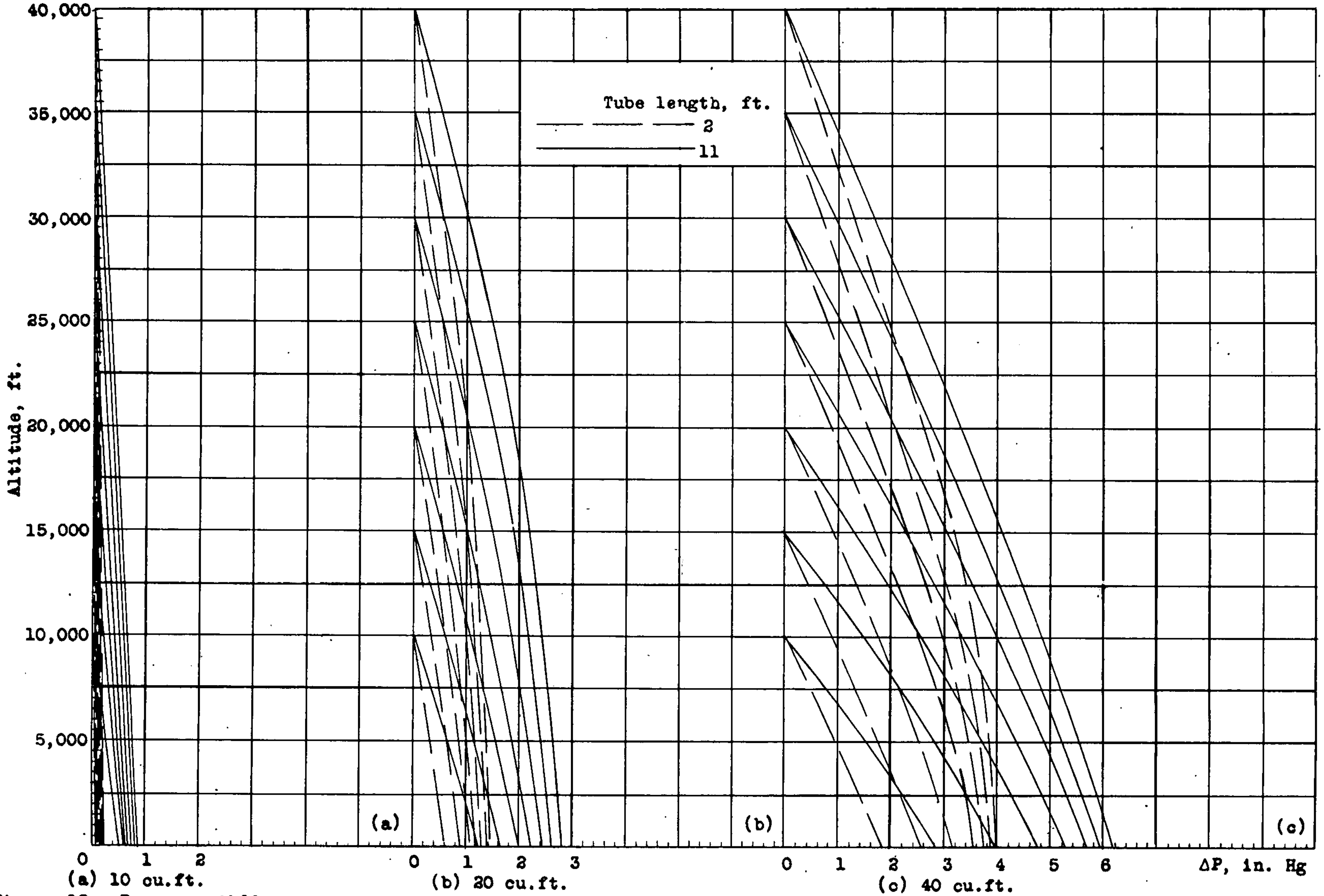


Figure 12.- Pressure difference developed during dives with a vent-tube inside dia. of 21/32 in. Terminal velocity, 300 m.p.h.

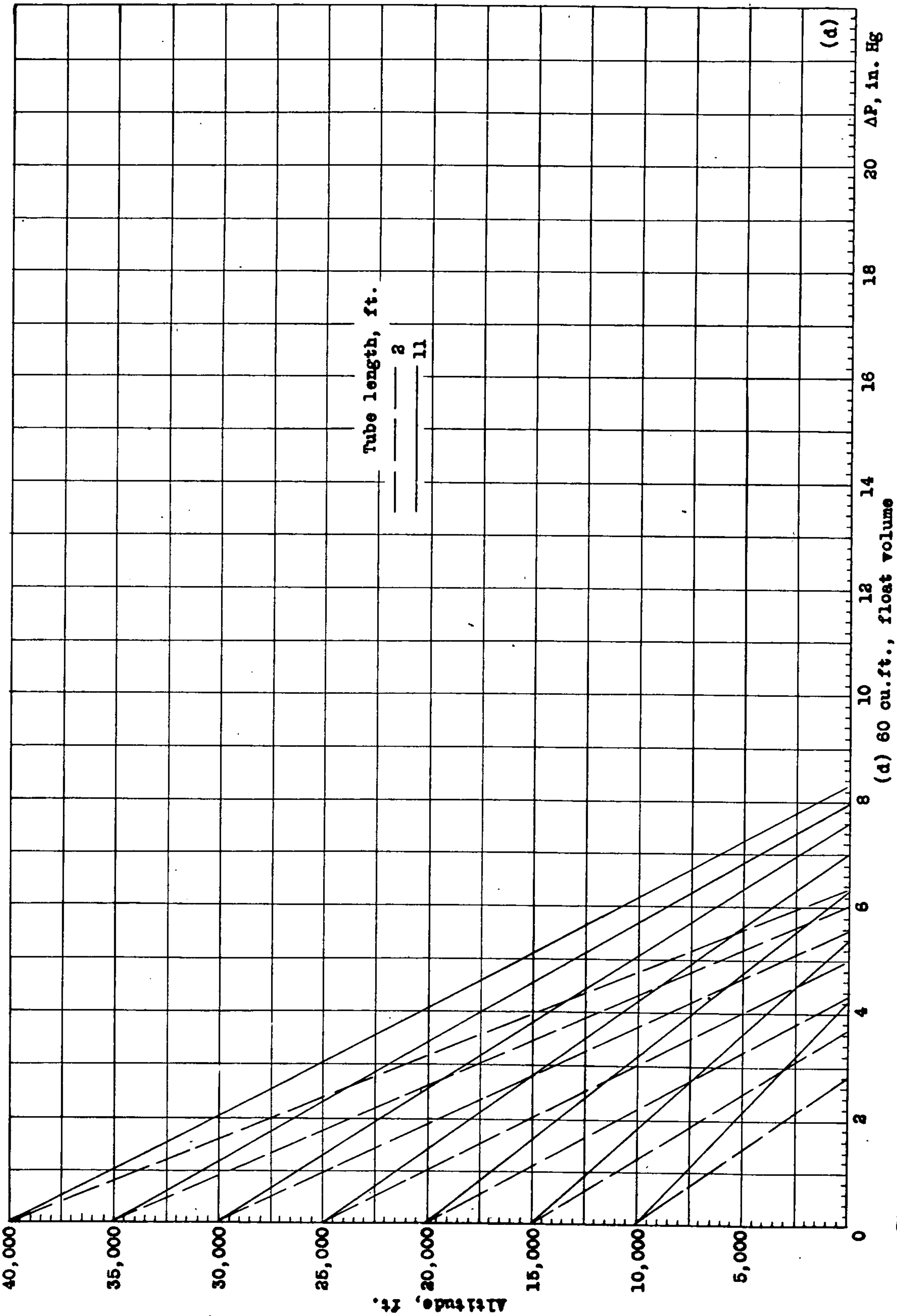

(d)
ΔP, in. Hg
0
2
4
6
8
10
12
14
16
18
20
Tube length, ft.
2
11
(d) 60 cu.ft., float volume
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
Altitude, ft.

Figure 12d.

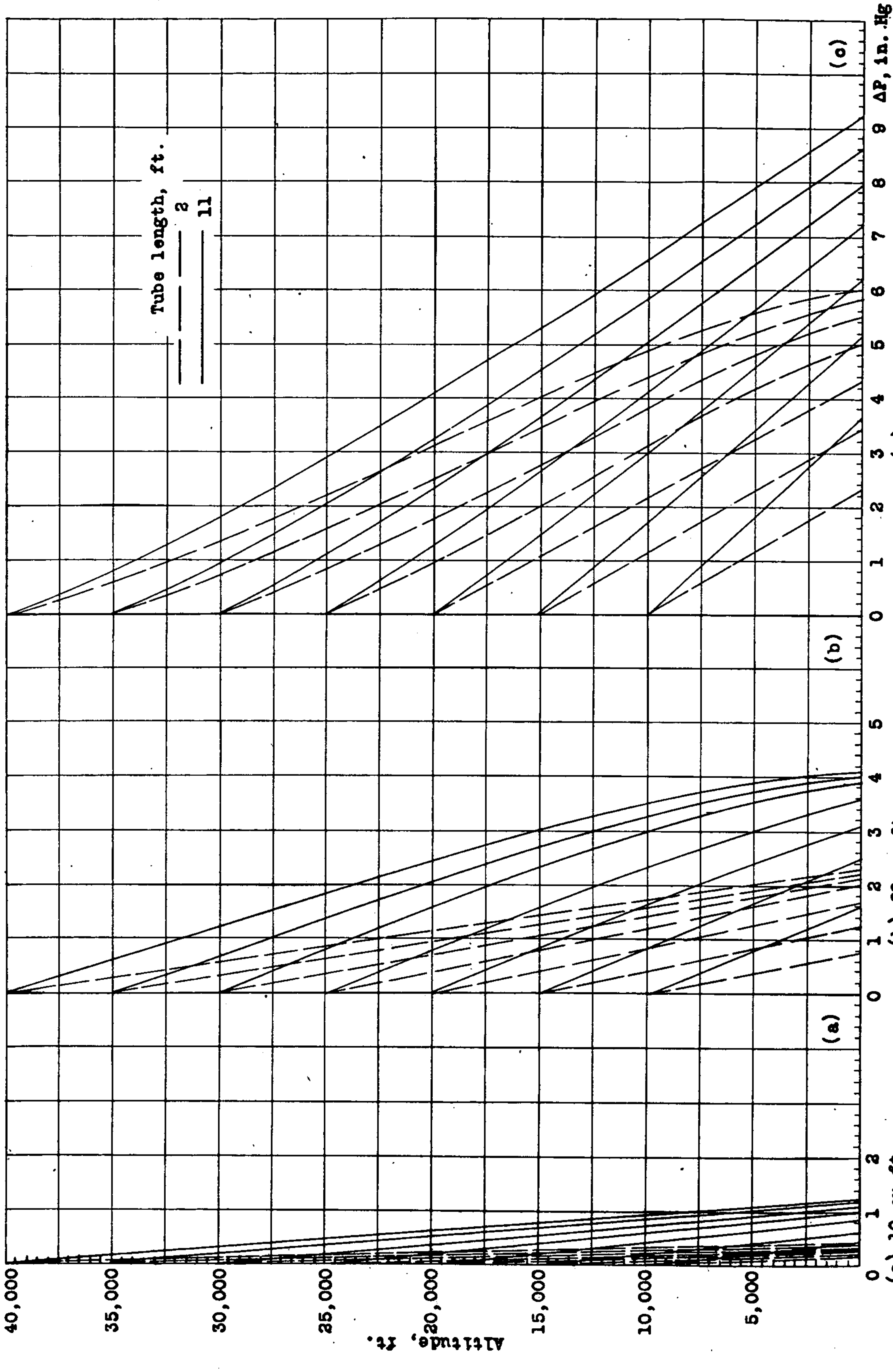


Figure 13.- Pressure difference developed during dives with a vent-tube inside diameter of 21/32 in. Terminal velocity, 400 m.p.h.

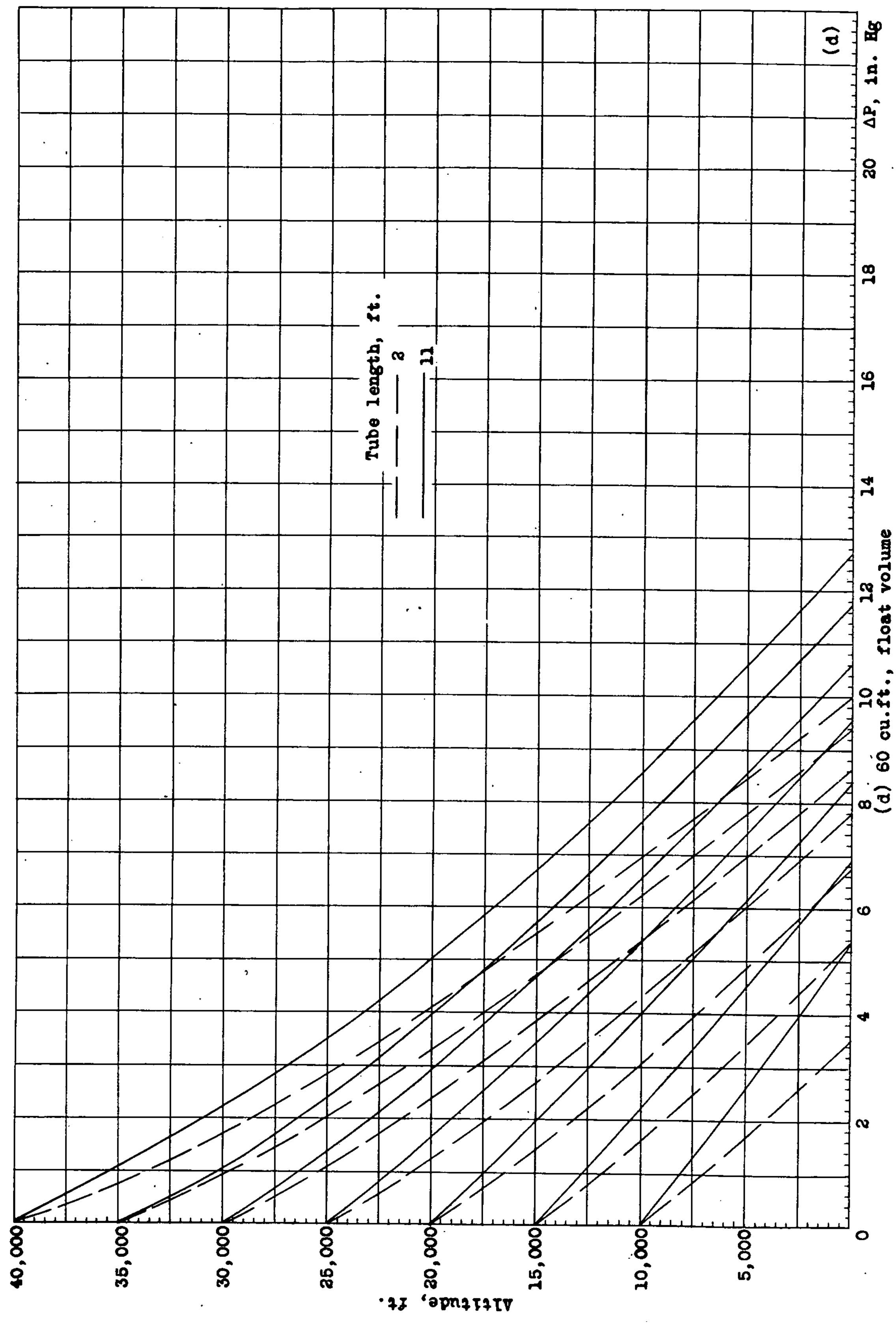

(d)
ΔP, in. Hg
0
2
4
6
8
10
12
14
16
18
20
Tube length, ft.
3
11
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
Altitude, ft.
(d) 60 cu.ft., float volume

Figure 13d.

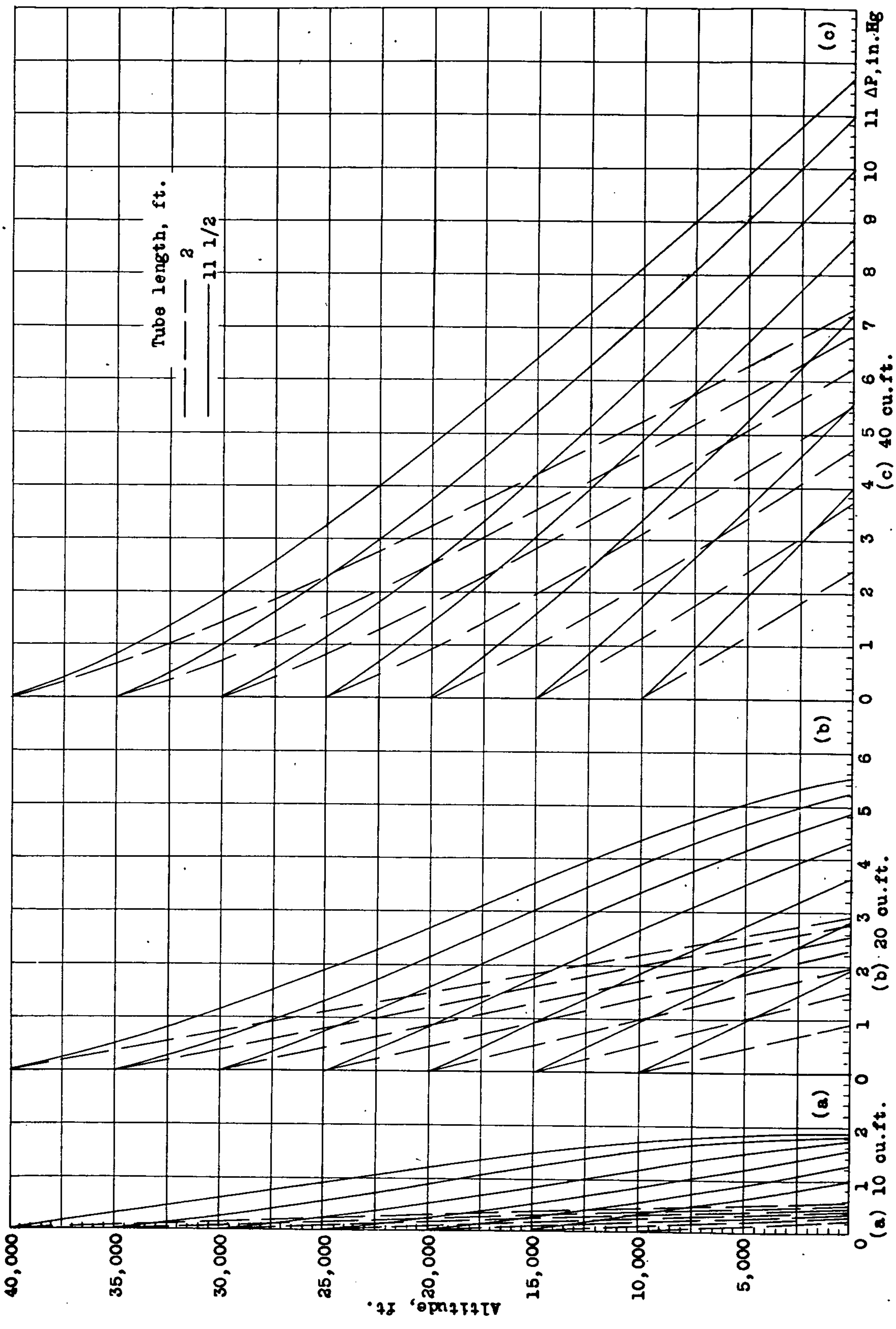
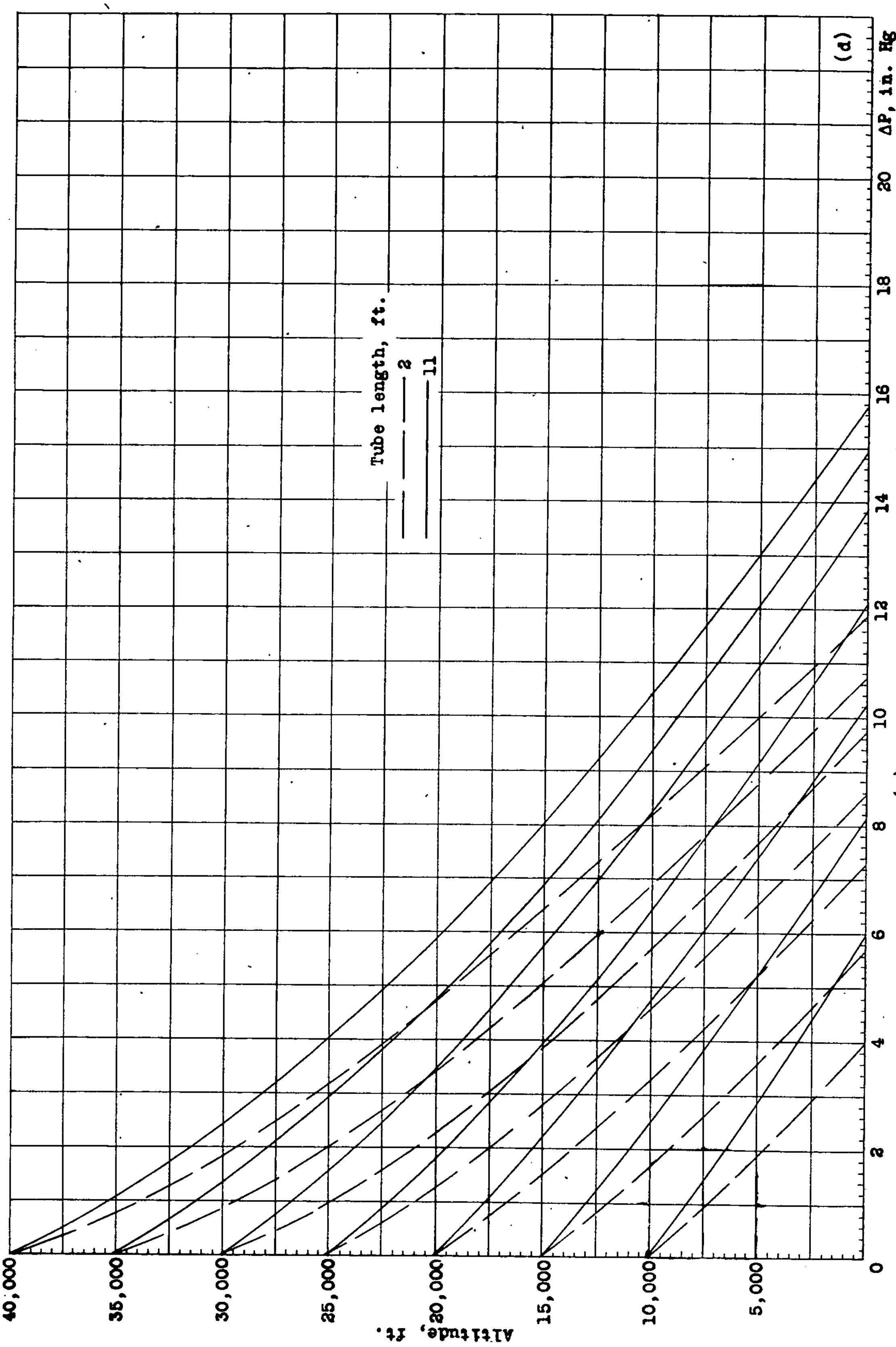


Figure 14.- Pressure difference developed during dives with a vent-tube inside diameter of 21/32 in. Terminal velocity, 500 m.p.h.



(d) 60 cu.ft., float volume

Figure 14d.

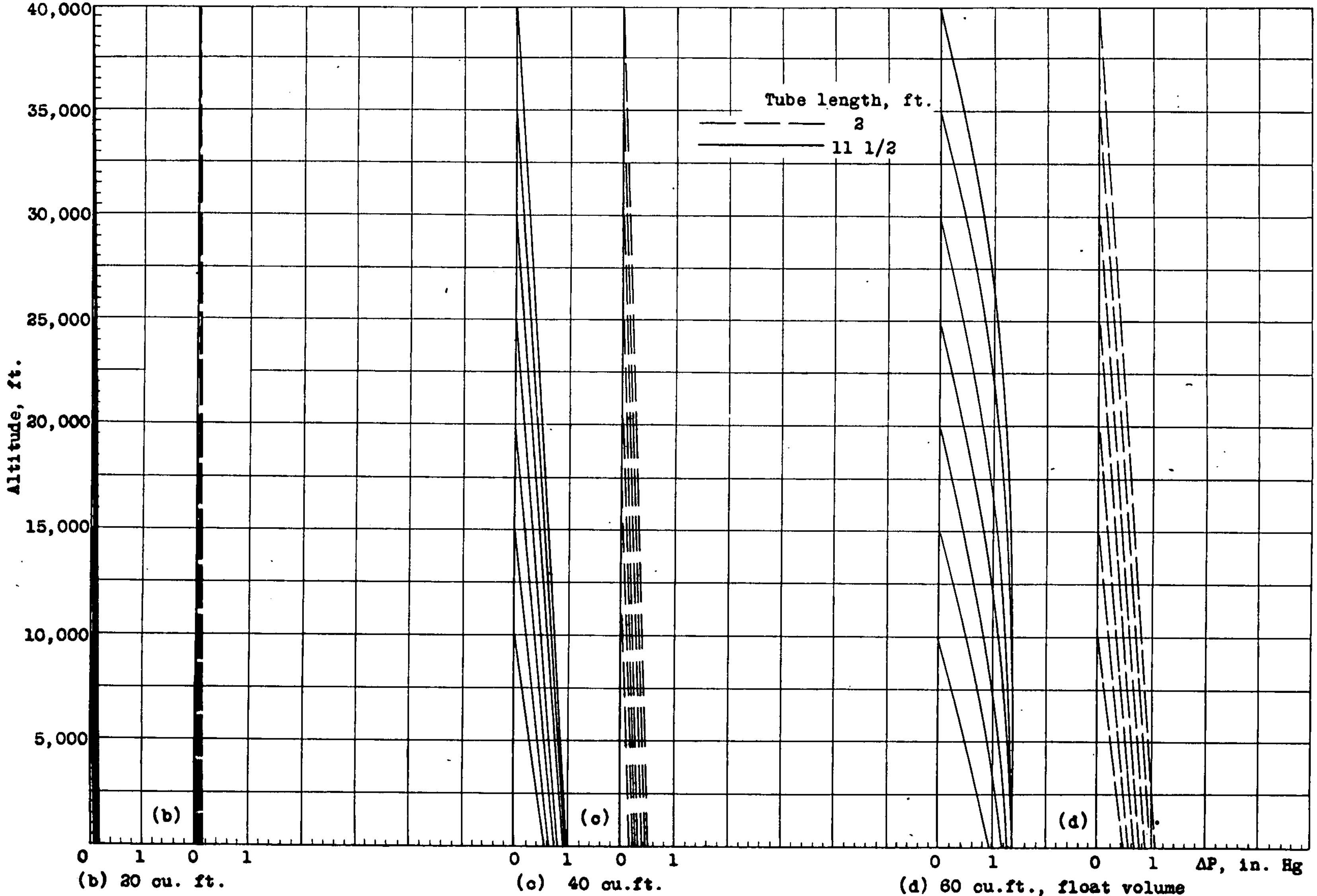


Figure 15.- Pressure difference developed during dives with a vent-tube inside diameter of 37/32 in. Terminal velocity, 300 m.p.h.

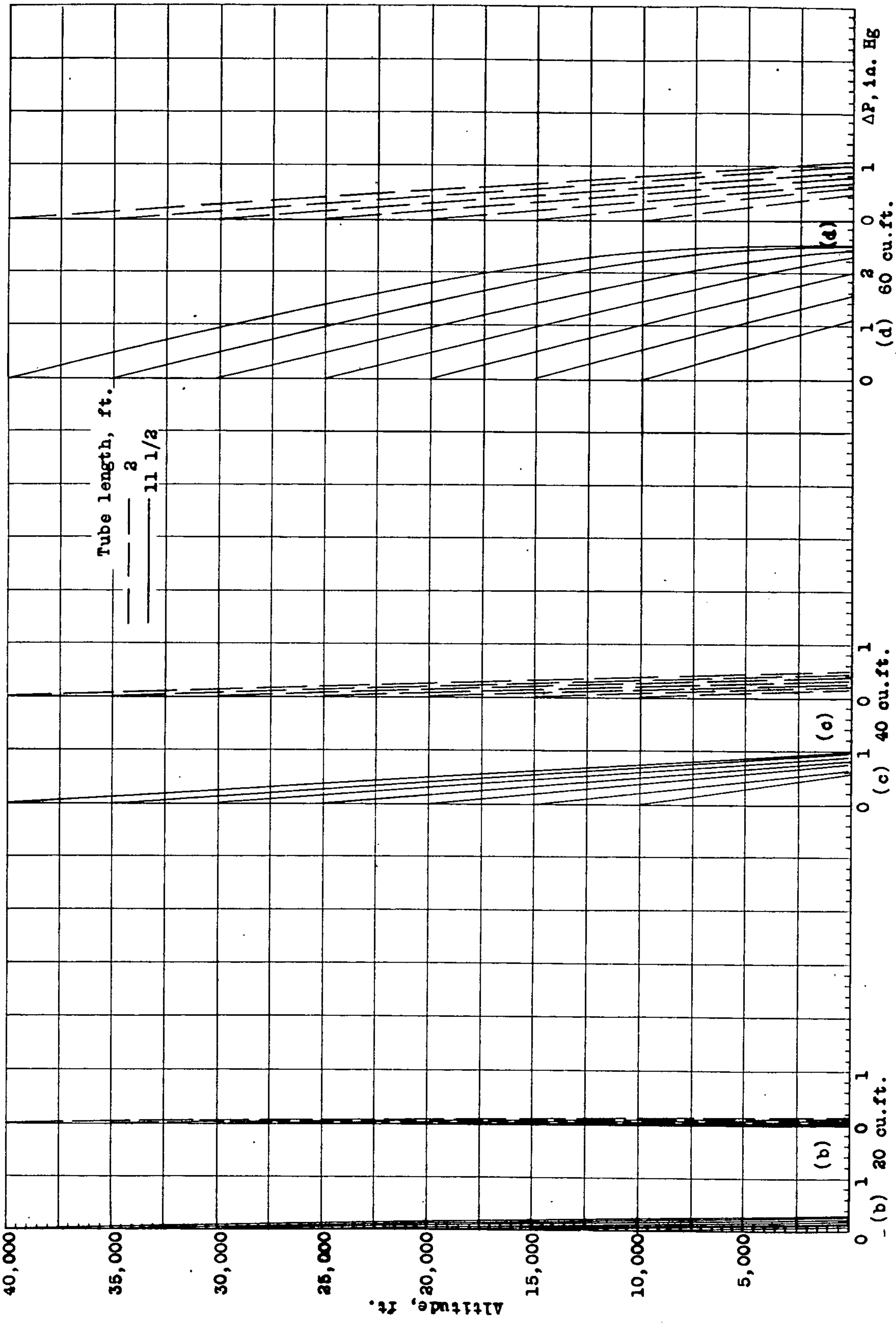


Figure 16.- Pressure difference developed during dives with a vent-tube inside diameter of 37/32 in. Terminal velocity, 400 m.p.h.

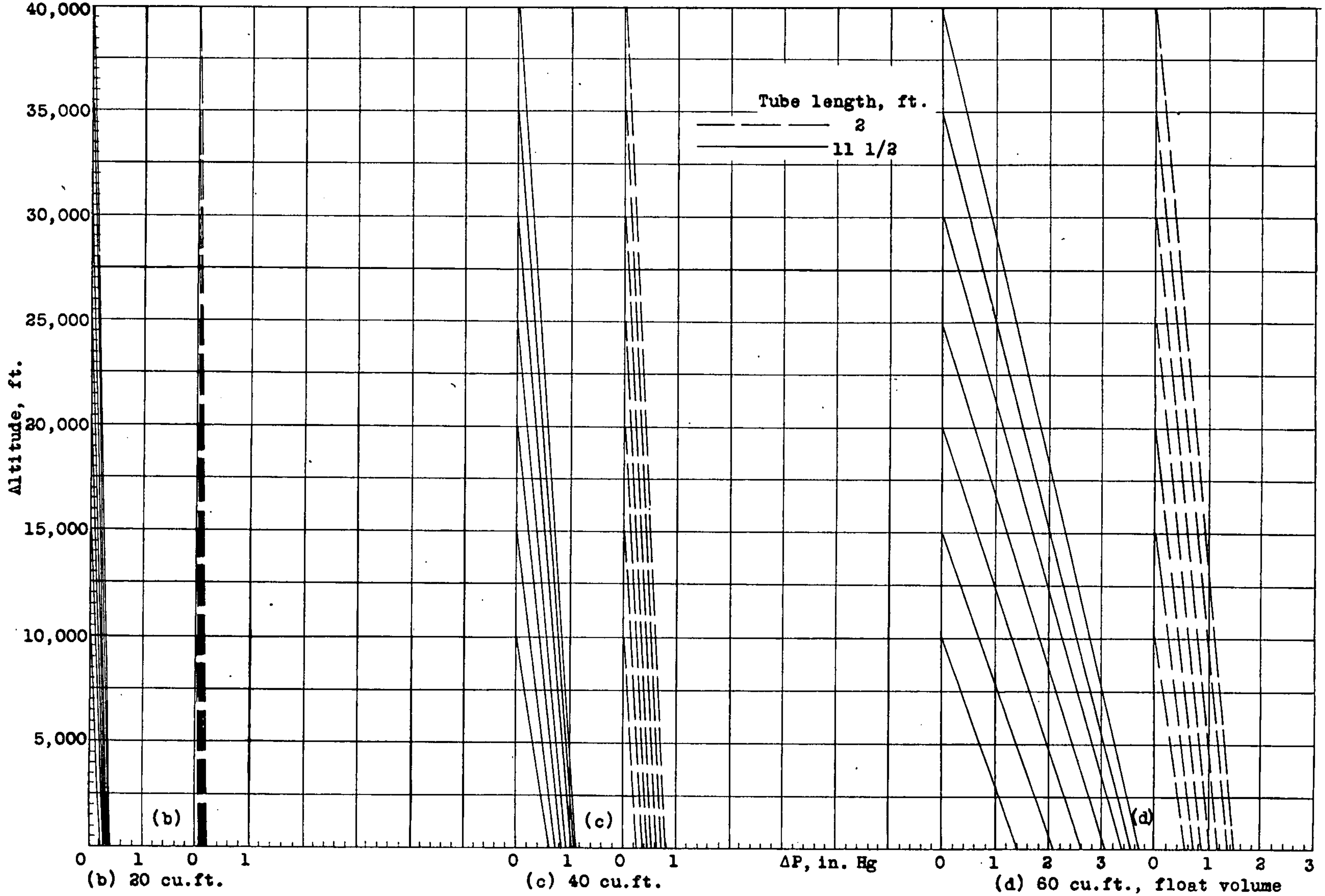


Figure 17.- Pressure difference developed during dives with a vent-tube inside diameter of 37/32 in. Terminal velocity, 500 m.p.h.

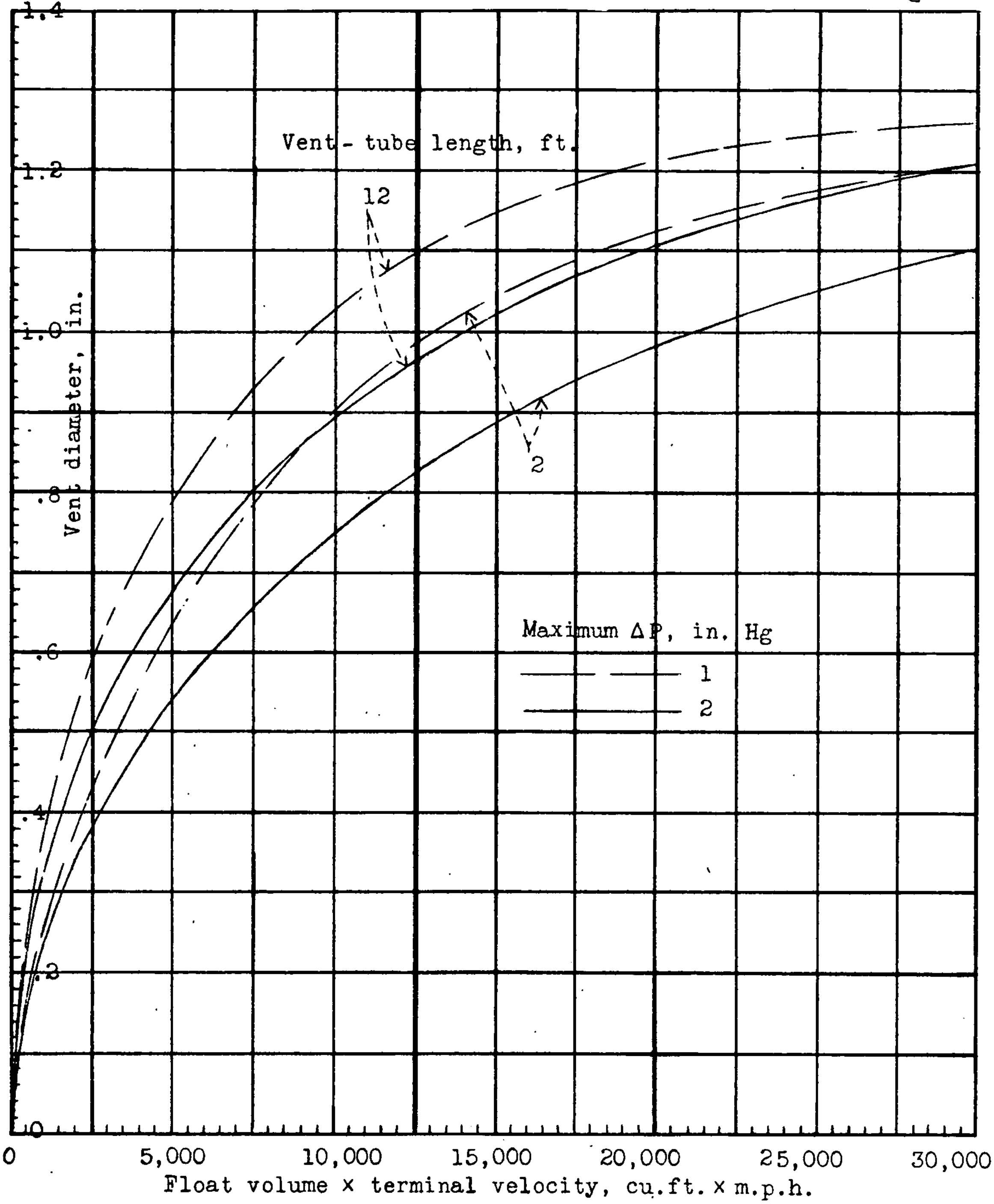


Figure 18.- Vent-tube diameter needed for maximum values of ΔP of 1 and 2 in. Hg Altitude of dive start, 40,000 ft.